For review only. Do not cite.

SURVIVAL ESTIMATES FOR THE PASSAGE OF SPRING-MIGRATING JUVENILE SALMONIDS THROUGH SNAKE AND COLUMBIA RIVER DAMS AND RESERVOIRS, 2001

by

Richard W. Zabel
Steven G. Smith
William D. Muir
Douglas M. Marsh
John G. Williams

Fish Ecology Division
Northwest Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112-2097

and

John R. Skalski
School of Fisheries
Center for Quantitative Science
University of Washington
Seattle, Washington 98195

Prepared for
U.S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
Contract DE-AI79-93BP10891
Project 93-29

December 2001

DRAFT

EXECUTIVE SUMMARY

In 2001, the National Marine Fisheries Service and the University of Washington completed the ninth year of a study to estimate survival and travel time of juvenile salmonids (*Oncorhynchus* spp.) passing through dams and reservoirs on the Snake and Columbia Rivers. All estimates were derived from passive integrated transponder (PIT) -tagged fish. We PIT tagged and released at Lower Granite Dam a total of 17,028 hatchery and 3,550 wild steelhead. In addition, we utilized fish PIT tagged by other agencies at traps and hatcheries upstream of the hydropower system and sites within the hydropower system. PIT-tagged smolts were detected at interrogation facilities at Lower Granite, Little Goose, Lower Monumental, McNary, John Day, and Bonneville Dams and in the PIT-tag detector trawl operated in the Columbia River estuary. Survival estimates were calculated using the Single-Release Model.

Primary research objectives in 2001 were to: 1) estimate reach and project survival and travel time in the Snake and Columbia Rivers throughout the yearling chinook salmon and steelhead migrations; 2) evaluate relationships between survival estimates and migration conditions; and 3) evaluate the survival-estimation models under prevailing conditions.

This report provides reach survival and travel time estimates for 2001 for PIT-tagged yearling chinook salmon and steelhead (hatchery and wild) in the Snake and Columbia Rivers. Results are reported primarily in the form of tables and figures with a minimum of text. More details on methodology and statistical models used are provided in previous reports cited in the text. Results for summer-migrating chinook salmon will be reported separately.

Precise survival rates for most of the 2001 yearling chinook salmon and steelhead migrations were estimated. Hatchery and wild fish were combined in some of the analyses. In the Snake River, fish tagged at or above Lower Granite Dam and subsequently recombined into

"release" groups at the dam, 76% of yearling chinook salmon and 70% of steelhead used in the analysis were hatchery-reared; 24% of yearling chinook salmon and 30% of steelhead were wild. Estimated survival from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam averaged 0.939 for yearling chinook salmon and 0.801 for steelhead. From Little Goose Dam tailrace to Lower Monumental Dam tailrace, estimated survival averaged 0.820 and 0.709; from Lower Monumental Dam tailrace to McNary Dam tailrace (including passage through Ice Harbor Dam), estimated survival averaged 0.720 and 0.296; from McNary Dam tailrace to John Day Dam tailrace, estimated survival averaged 0.758 and 0.337; and from John Day Dam tailrace to Bonneville Dam tailrace (including passage through The Dalles Dam), estimated survival averaged 0.645 and 0.753 for yearling chinook salmon and steelhead, respectively. The overall estimates of yearling chinook salmon and steelhead survival from Lower Granite Dam tailrace to Bonneville Dam tailrace (7 projects) were 0.276 (s.e.: 0.016) and 0.042 (s.e.: 0.003) respectively.

Flow levels during the 2001 spring migration period were the lowest recorded during the nine years of this study. Springtime spill was also very limited in 2001. Estimated survival from Lower Granite Dam to the tailrace of Bonneville Dam was the lowest recorded in the past nine years for spring chinook salmon and steelhead. Travel times of fish over this stretch of river were also greatly extended.

Spill during the 2001 migration season occurred during single, discrete periods at McNary, John Day, The Dalles, and Bonneville Dams. This allowed us to break survival estimates into pre-, during-, and post-spill treatment blocks for several stocks of chinook salmon and steelhead migrating past these dams. We tested whether survival was higher during periods of spill. The results of this analysis were inconsistent across stocks and sites.

CONTENTS

INTRODUCTION

Survival estimates for juvenile chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*O. nerka*), and steelhead (*O. mykiss*) that migrate through reservoirs, hydroelectric projects, and free-flowing sections of the Snake and Columbia Rivers are essential to develop effective strategies for recovering depressed stocks. Many present management strategies were based on estimates of system survival (Raymond 1979, Sims and Ossiander 1981) derived in a river system considerably different from today's (Williams and Matthews 1995). Knowledge of the magnitude, locations, and causes of smolt mortality under present passage conditions, and under conditions projected for the future, are necessary to develop strategies that will optimize smolt survival during migration.

From 1993 through 2000, the National Marine Fisheries Service (NMFS) and the University of Washington (UW) demonstrated the feasibility of using three statistical models to estimate survival of PIT-tagged (Prentice et al. 1990a) juvenile salmonids passing through Snake River dams and reservoirs (Iwamoto et al. 1994; Muir et al. 1995, 1996, 2001a; Smith et al. 1998, 2000a, b; Hockersmith et al. 1999, Zabel et al. 2001). Evaluation of assumptions for these models indicated that all were generally satisfied, and accurate and precise survival estimates were obtained.

In 2001, NMFS and UW completed the ninth year of the study. Research objectives were to: 1) estimate reach and project survival and travel time in the Snake and Columbia Rivers throughout the yearling chinook salmon and steelhead migrations; 2) evaluate relationships between survival estimates and migration conditions; and 3) evaluate the performance of the survival-estimation models under prevailing operational and environmental conditions. River conditions in 2001 were somewhat unique. Flow levels during the spring migration were the lowest recorded in the nine years of this study and the the lowest since the mid-1970s. Spill at dams was also very limited. Results from this year's study will provide valuable information on the survival and travel time of spring-migrating juvenile salmonids during low flow and spill conditions.

METHODS

Experimental Design

The Single-Release (SR) Model was used to estimate survival for releases of PIT-tagged yearling chinook salmon, sockeye salmon, and steelhead from Snake River Basin hatcheries and traps and from Lower Granite Dam in 2001 (Cormack 1964, Jolly 1965, Seber 1965, Skalsi 1998Skalski et al. 1998, Muir et al. 2001a,b). Iwamoto et al. (1994) presented background information and underlying statistical theory.

During the 2001 migration season, automatic PIT-tag detectors (Prentice et al. 1990a,b,c) were operational in the juvenile bypass systems at Lower Granite (RKm 695), Little Goose (RKm 635), Lower Monumental (RKm 589), McNary (RKm 470), John Day (RKm 347), and Bonneville (Rkm 234) Dams (Fig. 1). Most PIT-tagged fish detected at Lower Granite Dam were transported for the multi-state comparative survival study in 2001. However, the majority of PIT-tagged fish detected at dams below Lower Granite Dam were diverted back to the river by slide gates (rather than barged or trucked downstream), which allowed for the possibility of detection of a particular fish at more than one downstream site (Marsh et al. 1999). The most downstream site for PIT-tag detections occurred in the Columbia River estuary between Rkm 65 and 84 where a two-boat trawl towed a PIT-tag detector (Ledgerwood et al. 2000).

For fish from the Snake River, we used the records of downstream PIT-tag detections in the SR Model to estimate survival from the point of release to Lower Granite Dam tailrace, from Lower Granite Dam tailrace to Little Goose Dam tailrace, from Little Goose Dam tailrace to Lower Monumental Dam tailrace, from Lower Monumental Dam tailrace to McNary Dam tailrace, from McNary Dam tailrace to John Day Dam tailrace, and from John Day Dam tailrace to Bonneville Dam tailrace. For fish from the upper Columbia River we estimated survival from the point of release to the tailrace of McNary Dam, from McNary Dam tailrace to John Day Dam tailrace, and from John Day Dam tailrace to Bonneville Dam tailrace.

Lower Granite Dam Tailrace Release Groups

During 2001, wild and hatchery steelhead were collected at the Lower Granite Dam juvenile facility, PIT tagged, and released in approximate proportion to their arrival at Lower Granite Dam throughout the migration season. No yearling chinook salmon were PIT tagged specifically for this study because sufficient numbers were already PIT tagged and released from Snake River Basin hatcheries and traps. For both yearling chinook salmon and steelhead tagged above Lower Granite Dam and subsequently detected at Lower Granite Dam and released to the tailrace, we created daily "release groups" according to the day they were detected at Lower Granite Dam. For steelhead, these groups were then combined with the fish tagged and released each day at Lower Granite Dam. Daily tailrace release groups were then pooled into weekly groups. For these groups leaving Lower Granite Dam, we estimated survival from Lower Granite Dam tailrace to McNary Dam tailrace.

McNary Dam Tailrace Release Groups

For both yearling chinook salmon and steelhead tagged at all locations in the Snake River above McNary Dam and for fish tagged in the upper Columbia River and subsequently detected at McNary Dam and released to the tailrace, we created daily "release groups" according to the day they were detected at McNary Dam. Daily tailrace release groups were then pooled into weekly groups. For weekly groups leaving McNary Dam, we estimated survival from McNary Dam tailrace to John Day Dam tailrace and from John Day Dam tailrace to Bonneville Dam tailrace.

Survival estimates to Bonneville Dam required the use of fish detected in the PIT-tag detector trawl in the Columbia River estuary (Ledgerwood et al. 2000). The trawl was operated 8 hours per day during early and late portions of the migration season, and 16 hours per day during the peak. Survival to the tailrace of Bonneville Dam was estimated for weekly McNary Dam release groups for which we estimated that at least 90% of the group passed the detector trawl location during the 16-hour sampling periods. Expected passage timing was determined from timing of detection at Bonneville Dam. In 2001, median passage from Bonneville Dam to the trawl location was approximately 2.1 and 2.5 days for yearling chinook salmon and steelhead, respectively.

Weighted mean estimates of survival from McNary Dam tailrace to Bonneville Dam tailrace were multiplied by the weighted mean estimate from Lower Granite Dam tailrace to McNary Dam tailrace to obtain an overall estimated mean survival probability from Lower Granite Dam tailrace to Bonneville Dam tailrace for yearling chinook salmon and steelhead.

Hatchery and Trap Release Groups

In 2001, most hatcheries in the Snake River Basin released PIT-tagged fish as part of research separate from the NMFS/UW survival study. We analyzed data from hatchery releases of PIT-tagged fish to provide estimates of survival for yearling chinook salmon, sockeye salmon, and steelhead from release to the tailrace of Lower Granite Dam and to points downstream. In the course of characterizing the various hatchery releases, preliminary analyses were performed to determine whether data from multiple release groups could be pooled to increase sample sizes. We neither intended nor attempted to analyze the experiments for which the hatchery groups were released.

For each hatchery, release groups were examined to determine suitability for survival analysis, and release groups were pooled where appropriate. The SR Model was applied to each resulting data set to estimate the same probabilities estimated for Lower Granite Dam tailrace releases.

Survival was also estimated for releases of wild and hatchery PIT-tagged yearling chinook salmon and steelhead from the Salmon, Snake, and Imnaha River traps to Lower Granite Dam tailrace and points downstream.

Data Analysis

Tagging and detection data were retrieved from the PIT-Tag Information System (PTAGIS) maintained by the Pacific States Marine Fisheries Commission.[1] Data were examined for erroneous records, inconsistencies, and data anomalies. Records were eliminated where appropriate, and all eliminated PIT-tag codes were recorded with the reasons for their elimination. For each remaining PIT-tag code, we constructed a record ("capture history") indicating at which dams the tagged fish was detected and at which it was not detected. Methods for data retrieval, database quality assurance/control, and construction of capture histories were

[1] Pacific States Marine Fisheries Commission, PIT-Tag Operations Center, 45 SE 82nd Drive, Suite 100, Gladstone, OR 97207.

the same as those used in past years (Iwamoto et al. 1994; Muir et al. 1995, 1996; Smith et al. 1998, 2000a, b; Hockersmith et al. 1999, Zabel et al. 2001).

These analyses were conducted with currently available data. It is possible, for a variety of reasons, that the data in the PTAGIS database may be updated in the future. Thus, estimates provided by NMFS in the future may differ slightly from those contained here.

Tests of Assumptions

As in past years, we tested the statistical validity of the SR Model as applied to the data generated from PIT-tagged juvenile salmonids in the Snake and Columbia Rivers by evaluating critical assumptions. All assumptions were generally met during 2001.

Survival Estimation

Estimates of survival probabilities under the SR Model are random variables, subject to sampling variability. When true survival probabilities are close to 1.0 and/or when sampling variability is high, it is possible for estimates of survival probabilities to exceed 1.0. For practical purposes, estimates should be considered equal to 1.0 in these cases.

When estimates for a particular river section or passage route were available from more than one release group, the estimates were often combined using a weighted average (Muir et al. 2001a). Weights were inversely proportional to the respective estimated relative variance (coefficient of variation squared). The variance of an estimated survival probability from the SR Model is a function of the estimate itself; that is, lower survival estimates tend to have smaller estimated variance. Consequently, we do not use the inverse estimated absolute variance in weighting because lower survival estimates have disproportionate influence, and the resulting weighted mean is biased toward the lower survival estimates. All survival estimates presented are from point of release (or the tailrace of a dam) to the tailrace of some downstream dam.

All survival analyses were performed using the statistical computer program SURPH ("Survival with Proportional Hazards") for analyzing release-recapture data, developed at the University of Washington (Skalski et al. 1993, Smith et al. 1994).

Travel Time

Travel times were calculated for yearling chinook salmon and steelhead from 1) Lower Granite Dam to Little Goose Dam, 2) Little Goose Dam to Lower Monumental Dam, 3) Lower Monumental Dam to McNary Dam, 4) Lower Granite Dam to McNary Dam, 5) Lower Granite Dam to Bonneville Dam, 6) McNary Dam to John Day Dam, 7) John Day Dam to Bonneville Dam, and 8) McNary Dam to Bonneville Dam. Travel time between any two dams was calculated for each fish detected at both dams as the number of days between last detection at the upstream dam (generally at a PIT-tag detector close enough to the outfall site that fish arrived in the tailrace within minutes after detection) and first detection at the downstream dam. Travel time included the time required to move through the reservoir to the forebay of the downstream dam and any delay associated with residence in the forebay, gatewells, or collection channel prior to detection in the juvenile bypass system.

To facilitate comparisons among the river sections, rate of migration in each section (kilometers per day) was also calculated. Lengths of the river sections are 60 km from Lower Granite Dam to Little Goose Dam, 46 km from Little Goose Dam to Lower Monumental Dam, 119 km from Lower Monumental to McNary Dam, 225 km from Lower Granite to McNary Dam, 461 km from Lower Granite to Bonneville Dam, 123 km from McNary Dam to John Day Dam, 113 km from John Day Dam to Bonneville Dam, and 236 km from McNary Dam to Bonneville Dam. Rate of migration through a river section was calculated as the length of the section (km) divided by the travel time (days) (which included any delay at dams as noted above). For each group, the 20th percentile, median, and 80th percentile travel times and migration rates were determined.

The true complete set of travel times for a release group includes travel times of both detected and undetected fish. However, using PIT tags, travel times cannot be determined for fish that traverse a river section but are not detected at both ends of the section. Travel time statistics are computed only from travel times for detected fish, which represent a sample of the complete set. Non-detected fish pass dams via turbines and spill, thus, their time to pass a dam is minutes to hours shorter than detected fish passing to the tailrace via the juvenile bypass system.

Historical Comparisons of Survival Estimates

We made several comparisons of this year's results to those obtained from previous NMFS/UW survival studies. In addition, we performed a "Sims and Ossiander"-type regression analysis of survival versus flow (Sims and Ossiander 1981). We used both results obtained from the current survival studies, 1993-2001 and results obtained from previous survival studies, 1973-1979. Per-project survival was calculated from annual estimates of survival from either Lower Granite reservoir or the tailrace of Lower Granite Dam to either the tailrace of McNary Dam or the tailrace of the lowest Snake River Dam possible (Williams et. al 2001). Per-project survival was the *n*-th root of the annual estimate, where *n* was the number of projects in the reach. The annual average flow exposure index was calculated as a weighted average of exposure indices for daily groups of fish leaving Lower Granite Dam (Smith et al. in press). Relative weights were equal to the number of fish in each daily group. Consistent with previous analyses, we regressed per-project survival against flow according to the equation $S = a \cdot Flow^b$.

This nonlinear regression analysis was conducted with the S-plus statistical software package (MathSoft 2000).

Analysis of the Effects of Spill on Juvenile Salmonid Survival

The river conditions in 2001 were unique compared to the previous years of the study (Figures 2, 3, and 4). No spill occurred at Snake River dams. Further, a particularly unusual feature at McNary and John Day Dams was that spill occurred as an approximately three-week "block" during the middle of the spring migration season (Figure 3); no spill occurred early or late in the season, and a constant low level of spill occurred in the middle of the season. At The Dalles and Bonneville Dams, no spill occurred prior to 16 May. While these spill regimes were not intended for experimental purposes, it allowed us to examine the effects of spill on the survival of juvenile salmonids migrating during the spring season.

The study reaches were Lower Monumental Dam to McNary Dam, McNary Dam to John Day Dam, and John Day Dam to Bonneville Dam. We analyzed each stock of yearling chinook salmon and steelhead that migrated through these reaches with substantial numbers of PIT-tagged individuals. Each stock was treated separately to examine for stock-specific effects. The stocks analyzed were: 1) Snake River spring-summer chinook salmon (hatchery and wild combined); 2) Yakima River spring chinook salmon (hatchery and wild combined); 3) upper Columbia River spring chinook salmon from the Leavenworth and Winthrop Hatcheries; 4) upper Columbia River summer-fall chinook salmon raised yearlings at the Turtle Rock Hatchery; and 5) Snake River steelhead (hatchery and wild combined). We analyzed each stock through all the reaches where reliable survival estimates were obtainable during at least two of the treatment blocks.

For each stock, we created release groups corresponding to three periods: pre-spill, spill, and post-spill. The timing of these release groups was designed such that the arrival timing at the downstream detection site corresponded to the spill periods. For each of these groups, survival and standard errors were estimated. If spill was the dominant effect in determining survival, we would expect elevated survival in the spill period relative to the pre- and post-spill periods. We developed a sequences of hypothesis tests that not only examined whether survival was higher during the spill period but also whether survival was the same before and after spill.

For each stock we tested the following sequence of hypotheses. First we tested whether the spill period was different than the non-spill periods:

H_{10}: $\hat{S}_{spill} = \hat{S}_{no-spill}$

H_{1A}: $\hat{S}_{spill} \neq \hat{S}_{no-spill}$

In the null hypothesis of this test, all three periods were treated as having the same survival. In the alternative hypothesis, the spill period was treated as having different survival from the pre- and post-spill periods, which were treated as having the same survival. If this null hypothesis was rejected, we then tested whether the pre- and post-spill periods were different from each other:

H_{20}: $\hat{S}_{pre-spill} = \hat{S}_{post-spill}$

H_{20}: All periods different

In the second test, the null hypothesis has the same setup as the alternative hypothesis of the first test. The alternative hypothesis of the second test then treats each period as having a different survival. All tests were based on a likelihood ratio test using the SURPH statistical software package (Skalski et al. 1993, Smith et al. 1994). The strongest case for a spill effect would result from the first hypothesis being rejected but not the second. This would support the hypothesis that survival during the spill period was different from the other two periods and that survival was the same during the pre- and post-spill periods.

The analysis described above assumes that no temporal trends in survival exist independent of spill effects. If temporal trends do exist, they can potentially confound the results. We looked for these effects in the stocks of yearling chinook salmon migrating through the McNary Dam to John Day Dam reach. We formed weekly release groups based on when the fish were detected at McNary Dam. The dates for the release groups were chosen such that the arrival timing at John Day Dam for the three groups in the middle of the season corresponded as closely as possible to the three week spill period. Survival and detection probabilities were estimated for each of these groups using methods presented in the sections above and then we inspected the results for temporal or stock-specific trends.

Survival Estimates from Point of Release to Bonneville Dam

We estimated survival from point of release to Bonneville Dam for several stocks from both the Snake and upper Columbia Rivers. These estimates were obtained by first estimating survival over shorter reaches based on weighted averages of daily or weekly release groups. These survival estimates were then combined together to compute a weighted average survival through the entire reach. The weighting scheme is described in the *Survival estimation* section. We pooled similar fish from different release sites when we re-formed release groups at downstream sites.

RESULTS

Lower Granite Dam Tagging and Release Information

During 2001, a total of 22,689 yearling chinook salmon (17,310 hatchery origin, 5,379 wild) that were PIT tagged and released upstream of Lower Granite Dam were detected at the dam and returned to the river. A total of 50,196 steelhead (34,890 hatchery origin, 15,306 wild) were released to the tailrace of Lower Granite Dam from fish either PIT tagged and released upstream and detected at the dam or PIT tagged at the dam. Not all these fish were included in the analyses because some passed Lower Granite early or late in the season when sample sizes were too low to produce reliable survival or travel time estimates.

Survival Estimation

Yearling chinook salmon

Survival probabilities were estimated for weekly groups of yearling chinook salmon released in the tailrace at Lower Granite Dam for 9 consecutive weeks from 6 April through 7 June. Survival estimates from Lower Granite Dam tailrace to Little Goose Dam tailrace averaged 0.939 (s.e. 0.006; Table 1). From Little Goose Dam tailrace to Lower Monumental Dam tailrace, estimated survival averaged 0.820 (s.e. 0.009). From Lower Monumental Dam tailrace to McNary Dam tailrace, estimated survival averaged 0.720 (s.e. 0.009). For the combined reach from Lower Granite Dam tailrace to McNary Dam tailrace, survival averaged 0.551 (s.e. 0.011). These survival estimates are weighted for the seasonal outmigration. We note, however, that although detection probabilities remained relatively constant throughout the migration, estimates of survival decrease considerably for weekly groups passing Lower Granite Dam after 17 May.

Survival probabilities were estimated for weekly groups of yearling chinook salmon released in the tailrace at McNary Dam for 6 consecutive weeks from 27 April through 7 June. From McNary Dam tailrace to John Day Dam tailrace, estimated survival increased steadily from 0.58 to 0.83 between late April/early May and the end of May, averaging 0.758 (s.e. 0.024; Table 2). From John Day Dam tailrace to Bonneville Dam tailrace estimated survival was variable, averaging 0.645 (s.e. 0.034). For the combined reach from McNary Dam to Bonneville Dam, estimated survival averaged 0.501 (s.e. 0.027), with little weekly variation. The product of the average estimates from Lower Granite Dam to McNary Dam and from McNary Dam to Bonneville Dam provided an overall survival estimate from Lower Granite Dam tailrace to Bonneville Dam tailrace of 0.276 (s.e. 0.016). The estimated survival through Lower Granite Reservoir and Dam (based on the combined survival of Snake River wild and hatchery chinook salmon releases from the Snake River trap from Table 25) was 0.956 (0.014). Thus, the estimated system survival was 0.264 (0.015).

Survival probability estimates from Lower Granite Dam tailrace to McNary Dam tailrace were also calculated separately for hatchery and wild yearling chinook salmon (Tables 3-4). Survival estimates for hatchery and wild yearling chinook salmon were similar. Estimated survival probabilities for daily Lower Granite Dam release groups of yearling chinook salmon (hatchery and wild combined) detected and released to the tailrace of Lower Granite Dam generally had decreasing survival through the season in the reaches below Little Goose Dam (Table 5, Fig. 5). Detection probability estimates for the weekly groups varied little in the Snake River during the season due to the absence of spill, but decreased later in the season at McNary, John Day, and Bonneville Dams when spill began (Tables 6-9). Daily detection probabilities for hatchery and wild fish combined varied throughout the season at Little Goose and Lower

Monumental Dams, but no temporal trends were apparent (Fig. 6). The daily detection probabilities at McNary Dam followed a general downward trend throughout the season (Fig. 6).

Steelhead

Survival probabilities were estimated for weekly groups of steelhead released in the tailrace of Lower Granite Dam for 9 consecutive weeks from 6 April through 7 June. Survival estimates from Lower Granite Dam tailrace to Little Goose Dam tailrace averaged 0.801 (s.e. 0.010; Table 10). From Little Goose Dam tailrace to Lower Monumental Dam tailrace, estimated survival averaged 0.709 (s.e. 0.008). From Lower Monumental Dam tailrace to McNary Dam tailrace, estimated survival averaged 0.296 (s.e. 0.010). For the combined reach from Lower Granite Dam tailrace to McNary Dam tailrace, there was a general weekly downward trend in estimated survival, with a seasonal average of 0.168 (s.e. 0.006). Survival probabilities were estimated for weekly groups of steelhead released in the tailrace of McNary Dam for 4 consecutive weeks from 4 May through 31 May. From McNary Dam tailrace to John Day Dam tailrace, estimated survival averaged 0.337 (s.e. 0.025; Table 11). From John Day Dam tailrace to Bonneville Dam tailrace estimated survival averaged 0.753 (s.e. 0.063). For the combined reach from McNary Dam to Bonneville Dam, estimated survival averaged 0.250 (s.e. 0.016). The product of the average estimates from Lower Granite Dam to McNary Dam and from McNary Dam to Bonneville Dam provided an overall average survival estimate from Lower Granite Dam tailrace to Bonneville Dam tailrace of 0.042 (s.e. 0.003). The estimated survival through Lower Granite Reservoir and Dam (based on the combined survival of Snake River wild and hatchery steelhead released from the Snake River trap from Table 25.) was 0.912 (0.007). Thus, the estimated system survival was 0.038 (0.003)

Survival probabilities were estimated separately for hatchery and wild steelhead from Lower Granite Dam tailrace to McNary Dam tailrace (Tables 12-13). Survival estimates for wild and hatchery fish were similar through all reaches. Estimated survival probabilities for daily release groups of steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam increased early in the season and then tended to decrease as the season progressed (Table 14, Fig. 7). Detection probability estimates for the daily and weekly groups also decreased as the season progressed in the Snake River (without spill) and the Columbia River (with spill later in the season) (Tables 15-18, Fig. 8).

Hatchery Releases

The survival probabilities of PIT-tagged hatchery yearling chinook salmon, sockeye salmon, and steelhead from release at Snake River Basin hatcheries to the tailrace of Lower Granite Dam and downstream dams varied among hatcheries (Tables 19-21), as did the detection probabilities at the detection sites (Tables 22-24). Only 5 out of 130 sockeye salmon released at Pettit Lake Creek were detected at Lower Granite Dam, and reliable survival estimates were not possible (Table 21). This extremely low level of detection, though, indicated that survival was likely very poor for these fish.

Fish Trap Releases

Survival probability estimates for juvenile salmonids PIT tagged and released from Snake River Basin traps were generally inversely related to distance of the traps to Lower Granite Dam (Table 25), whereas the detection probabilities were similar among release groups from different traps (Table 26).

Travel Time

Travel time estimates for yearling chinook salmon and juvenile steelhead released in the tailraces of Lower Granite and McNary Dams varied throughout the season (Tables 27-34, Fig. 9). For both species, migration rates were generally highest in the lower river sections. Migration rates generally increased over time as flows, water temperatures, and levels of spill increased and, presumably, as fish became more smolted. With the much reduced flow in 2001, median travel times over all reaches were considerably longer than in the previous 8 years. This resulted in Snake River spring-summer chinook salmon and steelhead taking approximately 10-30 more days than previous years to complete the migration from Lower Granite Dam to Bonneville Dam (Fig. 9).

Tagging Details for Hatchery Steelhead Pit Tagged at Lower Granite Dam

Hatchery (16,981) and wild (3,552) steelhead were tagged from 11 April through 9 June at Lower Granite Dam for survival estimates (Table 35 and 36). Mortality and tag loss were less than 1 percent.

Historical Comparison of Survival Estimates

Estimates of survival from Snake River Basin hatcheries to Lower Granite Dam tailrace were similar or higher to those made in past years. Over the years of the study, a consistent inverse relationship has existed between the migration distance from the release site to Lower Granite Dam and the estimated survival through that reach (Fig. 10). For 1993-2001 estimates, the negative linear correlation between migration distance and estimated survival is significant (R^2 = 51.7%, $P < 0.0001$).

For yearling chinook salmon, survival was similar to that estimated in previous years for the Lower Granite to Little Goose Dam reach but lower than previously observed in the downstream reaches to McNary Dam (Fig. 11). For steelhead, survival estimates were lower in all Snake River reaches compared to previous observations and was particularly low in the reach from Lower Monumental to McNary Dam (Fig. 11).

Average per-project survival (one "project" is one reservoir/dam combination) since initiation of our survival studies in 1993 was estimated for each year by averaging the yearly reach estimates (estimates covered two to seven projects). Per-project survival was the lowest yet measured for spring chinook salmon and steelhead (Fig. 12), with steelhead per-project survival much lower than the lowest previous observation.

None of the regressions between per-project survival and flow index for Snake River chinook salmon within the lower Snake River reach were significant ($\alpha = 0.05$, Table 37, Fig. 13), regardless of which groupings of years were used. The year groupings that included data from the 1970s had the lowest *P*-values and the highest values of the effects parameter (*b*). Year groupings that included only data from the last decade (i.e., only PIT-tag data) had high *P*-values and shallow slopes, indicating little support for a survival-flow relationship during this period. Adding the 2001 data point, which resulted from the lowest flows recorded during the latter period, to the previous eight years of data changed overall results very little. Linear regressions performed on the same data yielded similar results.

Results from the 2001 studies provide estimates of survival only during the downstream portion of the migration. We will analyze these data in conjunction with adult returns that will occur over the next three years to determine whether variations in spill, flow, temperature, and passage route produce patterns in smolt-to-adult survival consistent with those observed during the downstream migration phase.

Analysis of the Effects of Spill on Juvenile Salmonid Survival

Before providing results of the analysis, we present a few limitations. First, the timing of the blocks were not randomly chosen. For spill at McNary and John Day dams, only three treatment periods resulted: early (no spill), middle (spill), and late (no spill). For spill at The Dalles and Bonneville Dams, only two treatments resulted: early (no spill) and late (spill). It is therefore difficult to discern spill effects from other confounding temporal effects. Also, survival was estimated from an upstream site to a downstream site, and the effects of spill are realized at the downstream site. Fish detected on the same day at the upstream site spread out as they migrate downstream, and thus although spill occurred during discrete periods, some fish in a single release group may have experienced spill conditions while others did not. Nevertheless, we believe the analyses can provide some insights into the effects of spill.

The weekly survival estimates and detection probabilities of chinook salmon migrating between McNary Dam and John Day Dam were similar among four stocks analyzed (Tables 38 and 39, Fig. 14). Survival increased gradually through the early part of the season and then dropped drastically for groups released on or after June 7th. This drop coincided with the post-spill period. Detection probabilities dropped somewhat during the spill period from the pre-spill period and then increased substantially after spill ceased (Table 39, Fig. 14). Note that the observed trend of survival increasing gradually through the early part of the season was also observed in previous years for Snake River yearling chinook salmon (Fig. 15, data taken from previous NMFS/UW survival reports). Because of this underlying temporal trend in survival, partitioning survival into broad treatment blocks is somewhat suspect. The statistical analysis assumes constant survival processes within each block and no overriding temporal trends among blocks. This assumption violation limits the utility of the results that follow.

Survival exhibited variability when release groups were pooled into pre-spill, spill, and post-spill periods (Table 40, Figs. 16 and 17). For the yearling chinook salmon stocks migrating from John Day to Bonneville Dam and the steelhead migrating from Lower Monumental to McNary Dam, we could not produce reliable survival estimates in the post-spill period. In seven out of nine cases, the null hypothesis that survival in all periods was equal was rejected (Table 40). In three out of the five cases where the subsequent hypothesis was testable, though, the hypothesis that the pre-spill and post-spill periods had different survival was also rejected, indicating that variability in survival existed that was not explained by the spill factor. The stocks for which this hypothesis wasn't rejected (Upper Columbia River and Yakima River spring chinook salmon) had very small sample sizes in the post-spill period, resulting in large standard errors and poor power to detect differences. In five of the stocks where survival during the spill period was significantly different from the other periods, it was higher. However, in the other two cases (Snake River spring-summer chinook salmon and steelhead migrating from Lower Monumental Dam to McNary Dam), survival was significantly higher in the pre-spill period than in the spill period.

Survival Estimates from Point of Release to Bonneville Dam

The upper Columbia River summer-fall chinook salmon had the highest estimated survival from release to Bonneville Dam: 0.523 (0.050) for fish released at Rock Island Dam, which migrated past six projects, and 0.487 (0.046) for fish released at Rocky Reach Dam, which migrated past seven projects (Table 41). The estimated survival of spring chinook released at hatcheries in the upper Columbia River was somewhat lower: 0.335 (0.084) for fish released at Leavenworth Hatchery, which migrated past six projects, and 0.286 (0.072) for fish released at Winthrop Hatchery, which migrated past eight projects. The fish released at Lower Granite Dam migrated past seven projects. Snake River spring-summer chinook salmon had an estimated survival from Lower Granite to Bonneville Dam of 0.276 (0.016), which was similar to that of the upper Columbia River spring chinook salmon. In contrast, Snake River steelhead had an estimated survival of 0.042 (0.003) from Lower Granite to Bonneville Dam.

DISCUSSION

The low flow and spill conditions in the Snake and Columbia Rivers that prevailed during the 2001 spring migration season led to low survival through the hydro-system for both Snake River spring-summer chinook salmon and steelhead. For chinook salmon, the estimated survival (27.6%) from Lower Granite Dam to Bonneville Dam was substantially lower than survival estimates in the previous 6 years (range 43-59%), which had moderate to high flow and spill levels. The estimated survival was close to those from 1993 and 1994 (34 and 31%, respectively), when relatively little spill occurred. Thus, the decrease in spill alone may explain much of the lower survival observed for chinook salmon during the 2001 migration season. In contrast, the estimated system-wide survival for spring chinook salmon in 2001 was substantially higher than the 3% estimated survival from the head of Lower Granite Dam reservoir to the tailrace of Bonneville Dam in 1973, a year with similar flow volumes (Williams et al. 2001). The 4.2% estimated survival for steelhead, though, was considerably lower than any estimates in the previous 8 years but similar to 1973, which had an estimated survival of 1%. We will discuss below some potential mechanisms for the alarmingly low steelhead survival observed in 2001.

The low flows in the Snake River also substantially increased travel times of chinook salmon and steelhead. Median travel time from Lower Granite to Bonneville Dam was approximately 10-30 days longer in 2001 compared to recent years. The limited spill levels in 2001 may have also contributed to longer travel times by increasing delay at the face of dams. Unfortunately, we have no way of distinguishing between spill effects and flow effects on the observed travel times. The extended travel times experienced in 2001 may have contributed to poor survival of juvenile salmonids by lengthening their exposure time to predators and by extending their residence in reservoirs into periods with higher temperatures (Fig. 4) when predators are more active (Vigg and Burley 1991). The protracted travel times in 2001 may also result in lower smolt-to-adult survival because fish arriving at the estuary later in the season potentially have lower survival during the smolt-to-adult life stage (Zabel and Williams In press).

As a consequence of the low flows, spill at Snake River dams did not occur in 2001 during the spring migratory period. This resulted in higher than usual collection efficiency, with approximately 93% of unmarked chinook salmon and 95% of unmarked steelhead that arrived at Lower Granite Dam subsequently transported from Lower Granite, Little Goose, and Lower Monumental Dams combined (the percentages are based on a ratio of estimated total PIT-tagged fish to Lower Granite Dam compared to the total number of actual first-time detected fish at the three collector dams). Thus, the consequences of the low-flow conditions in 2001 on Snake River stocks will depend almost entirely on the adult return rate of the transported fish. Only a very small percentage of unmarked Snake River fish were subjected to the poor migratory conditions faced by migrants passing downstream though the hydropower system.

The high percentage of fish transported in 2001 had another important consequence: the overall abundance of Snake River juvenile salmonids below Lower Monumental Dam likely was extremely low compared to previous years, and the vast majority of these fish were PIT-tagged fish that were diverted back into the river. This may have influenced predator/prey dynamics for the PIT-tagged fish and had a large impact on their survival. Another factor potentially affecting predator-prey dynamics in 2001 was the above-average water clarity[2], making salmonid smolts more susceptible to visual predators (Gregory and Levings 1998). Steelhead are particularly susceptible to predation by birds; Collis et al. (2001) found that greater than 15% of the PIT-tagged steelhead entering the Columbia River estuary in1998 were later found on Rice Island, the home of the largest Caspian tern colony in western North America. Crescent Island in McNary Pool harbors the second largest Caspian tern colony in western North America in addition to extensive populations of gulls and other avian piscivores. In fact, over 5,000 PIT tags from steelhead tagged in 2001 were recovered on Crescent Island (Brad Ryan, NMFS, pers. comm.). Based on preliminary analyses, of all the PIT-tagged steelhead detected at Lower Monumental Dam, 14.2 percent were later detected on Crescent Island. This percent detection represents a minimum estimate of mortality due to tern predation since not all tags were detected. Correspondingly, per-project survival for steelhead was substantially lower in the Lower Monumental to McNary Dam reach (two projects, $0.296^{1/2} = 0.544$) compared to the Lower Granite to Little Goose Dam reach (0.801) and the Little Goose to Lower Monumental Dam reach (0.709). Also, estimated steelhead survival from McNary to John Day Dam (0.337) was substantially lower than estimated per-project survival from John Day to Bonneville Dam (two projects, $0.753^{1/2} = 0.868$). In contrast, 4.1 percent of spring-summer chinook salmon detected at Lower Monumental Dam were subsequently detected on Crescent Island, and the per-

[2] Data available at http://www.cbr.washington.edu/dart/river.html

project survival estimates for the reaches directly above and below McNary Dam were not substantially depressed compared to other reaches.

The low flows and lack of spill at Snake River dams in 2001 may have contributed to low estimates of steelhead survival in another way. Steelhead have a complex life history and are known to residualize, and steelhead not detected during the 2001 migration season were counted as mortalities in the survival model. Zaugg and Wagner (1973) found that gill Na^+-K^+ ATPase (an indicator of migratory readiness) and migratory urge declined at water temperatures of 13ºC and above. In 2001, an above-average year for water temperature, temperature exceeded 13ºC by the beginning of May (Fig. 4). Extremely protracted travel times resulted in many steelhead experiencing water temperatures above 13ºC for an extended time. Whether larger numbers of residualized fish will over-winter in the reservoirs and resume their migration in 2002 is doubtful. In previous years, the proportion of steelhead that residualized and successfully migrated the following year has been extremely low. Of the 229,006 wild and hatchery steelhead PIT-tagged and released from the Snake River trap, Salmon River trap, and Lower Granite Dam between 1994 and 2000 (1999 was excluded due to a change in PIT-tag technology between the 1999 and 2000 seasons), only 221 (0.1%) were detected the following year. Almost all of those (194) were from the 1994 migration, the second lowest flow year since PIT tag survival studies began when 0.5% were detected the following year. Additional steelhead may have migrated during the time period that bypass systems and PIT tag detectors were not operated (winter months), but the numbers were likely small. Based on these data, we might expect to see some juvenile steelhead tagged in 2001 continuing their migration in 2002, but we doubt their numbers will be large enough to substantially alter survival estimates.

The positive effects of spill have been demonstrated previously on a season-wide basis. Analyses based on early data (1973-1979) suggested that increases in spill had a very direct and sharp impact on increasing survival (Sims and Ossiander 1981). Our own survival studies indicate that survival through the hydropower system in 1993 and 1994 was lower when spill occurred only in excess of powerhouse capacity compared to system-wide survival after spill was designated at all dams by the 1995 Biological Opinion (NMFS 1995). Demonstrating the in-season effects of spill has been more problematic (Smith et al. in press). This year was no exception as it was difficult to tease out spill effects from underlying temporal trends that existed independent of spill levels. Although survival of yearling chinook salmon passing John Day Dam was higher during the spill period than before, the weekly estimates of survival had an increasing trend prior to and during spill (Fig. 14), a temporal trend evident in previous years for Snake River yearling chinook salmon(Fig. 15). Thus if we had applied the same cutoff dates to the previous years' data (when no systematic differences in spill patterns existed), we likely would have obtained the same results: higher survival in the later period compared to the earlier period. Also, the results were inconsistent across reaches. For instance, survival of fish passing from Lower Monumental Dam to John Day Dam was actually higher in the non-spill period at McNary Dam than during the spill period.

The fact that spill benefits were not strongly exhibited this year does not mean they do not exist. As mentioned above, the experimental design that we happened upon this year was by no means ideal. Further, when spill did occur, it was at levels far below those of the previous six years (Fig. 3). Finally the potential positive effects of spill likely go beyond those directly measured as project survival. Smith et al. (in press) found a strong inverse relationship between travel time and spill exposure in the Snake River for both yearling chinook salmon and steelhead. In 2001, with limited or no spill at dams, median travel times were 10 to 30 days longer from Lower Granite to Bonneville Dam for both yearling chinook salmon and steelhead, although part of this protracted migration was also due to low flow levels. The protracted travel times in 2001 potentially had several detrimental effects on salmonid survival: extending the migration into periods of high reservoir temperatures, increasing the likelihood of residualization in steelhead, and delaying entry into the estuary. Resolving these issues would require a more rigorous experimental design that included more numerous spill blocks randomly spaced throughout the season and occurring at several dams. If we also wanted to determine response of fish to different levels of spill, we would need to vary the level of spill during blocks. Also, to measure indirect effects, we would have to follow fish to their return as adults. Given the potential complexity of an experiment that would address all these issues, its feasibility would require careful consideration.

RECOMMENDATIONS

Successful validation of field and statistical methodologies in 2001 formed the basis for the following recommendations for 2002 and future years:

1) Future survival studies should continue to be coordinated with other projects to maximize the data-collection effort and minimize study effects on salmonid resources.

2) To date, little mortality has been found in Lower Granite and other reservoirs investigated (in most years). Estimates of survival from hatcheries to Lower Granite Dam indicate that substantial mortality occurs upstream from the Snake and Clearwater River confluence. Efforts should continue to identify where this mortality occurs.

3) Increasing the number of detection facilities in the Columbia River Basin will improve survival investigations. We recommend installation of detectors and diversion systems at The Dalles and upper-Columbia River dams. The development of flat-plate detector technology in bypass systems and portable streambed flat-plate detectors for use in tributaries would greatly enhance survival estimation capabilities.

ACKNOWLEDGMENTS

We express our appreciation to all who assisted with this research. Carter Stein and staff of the Pacific States Marine Fisheries Commission provided valuable assistance in data acquisition. Fish Ecology Division staff from several research stations participated in the study. Tom Ruehle, Scott Davidson, Eric Hockersmith, and other staff at the Pasco Field Station coordinated much of the planning and operational elements and minimized potential logistical problems. Ben Sandford gathered data on the occurrence of residualization in steelhead.

Support for this research came from the region's electrical ratepayers through the Bonneville Power Administration and the National Marine Fisheries Service.

REFERENCES

Collis, K., D. D. Roby, D. P. Craig, B.R. Ryan, and R. D. Ledgerwood. 2001. Colonial waterbird predation on juvenile salmonids tagged with passive integrated transponders in the Columbia River Estuary: Vulnerability of different salmonid species, stocks, and rearing types. Transactions of the American Fisheries Society 130:385-396.

Cormack, R. M. 1964. Estimates of survival from the sightings of marked animals. Biometrika 51:429-438.

Gregory, R. S., and C. D. Levings. 1998. Turbidity reduces predation on migrating juvenile Pacific salmon. Transactions of the American Society 127: 275-285.

Hockersmith, E. E., S. G. Smith, W. D. Muir, B. P. Sandford, J. G. Williams, and J. R. Skalski. 1999. Survival estimates for the passage of juvenile salmonids through Snake River dams and reservoirs, 1997. Report to Bonneville Power Administration, Contract DE-AI79-93BP10891, 60 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Iwamoto, R. N., W. D. Muir, B. P. Sandford, K. W. McIntyre, D. A. Frost, J. G. Williams, S. G. Smith, and J. R. Skalski. 1994. Survival estimates for the passage of juvenile chinook salmon through Snake River dams and reservoirs, 1993. Report to Bonneville Power Administration, Contract DE-AI79-93BP10891, 126 p. plus Appendixes. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Jolly, G. M. 1965. Explicit estimates from capture-recapture data with both death and immigration--stochastic model. Biometrika 52:225-247.

Ledgerwood, R. D., B. A. Ryan, E. P. Nunallee, and J. W. Ferguson. 1997. Estuarine recovery of PIT-tagged juvenile salmonids from the Lower Granite Dam transportation study, 1998. Final Report to the U.S. Army Corps of Engineers, Contract E8960100, 50 p. plus appenices. (Available from the Northwest Fisheries Science Center, 2725 Montlake Blvd. E, Seattle, WA, 98112-2097)

Marsh, D. M., G. M. Matthews, S. Achord, T. E. Ruehle, and B. P. Sandford. 1999. Diversion of salmonid smolts tagged with passive integrated transponders from an untagged population passing through a juvenile collection system. N. Am. J. Fish. Manage. 19:1142-1146.

MathSoft. 2000. S-Plus 6.0 Guide to statistics, Volume 1. Data Analysis Products Division, MathSoft, Seattle, Washington.

Muir, W. D., S. G. Smith, E. E. Hockersmith, S. Achord, R. F. Absolon, P. A. Ocker, B. M. Eppard, T. E. Ruehle, J. G. Williams, R. N. Iwamoto, and J. R. Skalski. 1996. Survival estimates for the passage of yearling chinook salmon and steelhead through Snake River dams and reservoirs, 1995. Report to Bonneville Power Administration, Contract DE-AI79-93BP10891, and U.S. Army Corps of Engineers, Project E86940119, 150 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Muir, W. D., S. G. Smith, R. N. Iwamoto, D. J. Kamikawa, K. W. McIntyre, E. E. Hockersmith, B. P. Sandford, P. A. Ocker, T. E. Ruehle, J. G. Williams, and J. R. Skalski. 1995. Survival estimates for the passage of juvenile salmonids through Snake River dams and reservoirs, 1994. Report to Bonneville Power Administration, Contract DE-AI79-93BP10891, and U.S. Army Corps of Engineers, Project E86940119, 187 p.

(Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Muir, W. D., S. G. Smith, J. G. Williams, E. E. Hockersmith, and J. R. Skalski. 2001a. Survival estimates for migrant yearling chinook salmon and steelhead tagged with passive integrated transponders in the Lower Snake and Columbia Rivers, 1993-1998. North American Journal of Fisheries Management 21:269-282.

Muir, W. D., S. G. Smith, J. G. Williams, and B. P. Sandford. 2001b. Survival of juvenile salmonids passing through bypass systems, turbines, and spillways with and without flow deflectors at Snake River Dams. North American Journal of Fisheries Management 21:135-146.

National Marine Fisheries Service (NMFS). 1995. Reinitiation of consultation on 1994-1998 operation of the federal Columbia River power system and juvenile transportation program for 1995 and future years. United States Department of Commerce, Silver Springs, Maryland. 166 p. + Appendices.

Prentice, E. F., T. A. Flagg, and C. S. McCutcheon. 1990a. Feasibility of using implantable passive integrated transponder (PIT) tags in salmonids. Am. Fish. Soc. Symposium 7:317-322.

Prentice, E. F., T. A. Flagg, C. S. McCutcheon, and D. F. Brastow. 1990b. PIT-tag monitoring systems for hydroelectric dams and fish hatcheries. Am. Fish. Soc. Symposium 7:323-334.

Prentice, E. F., T. A. Flagg, C. S. McCutcheon, D. F. Brastow, and D. C. Cross. 1990c. Equipment, methods, and an automated data-entry station for PIT tagging. Am. Fish. Soc. Symposium 7:335-340.

Raymond, H. L. 1979. Effects of dams and impoundments on migrations of juvenile chinook salmon and steelhead from the Snake River, 1966 to 1975. Trans. Am. Fish. Soc. 108(6):505-529.

Seber, G. A. F. 1965. A note on the multiple recapture census. Biometrika 52:249-259.

Sims, C., and F. Ossiander. 1981. Migrations of juvenile chinook salmon and steelhead in the Snake River, from 1973 to 1979, a research summary. Report to the U.S. Army Corps of Engineers, Contract DACW68-78-0038, 31 p. plus Appendix. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Skalski, J. R. 1998. Estimating season-wide survival rates of outmigrating salmon smolt in the Snake River, Washington. Canadian Journal of Fisheries and Aquatic Sciences 55:761-769.

Skalski, J. R., A. Hoffmann, and S. G. Smith. 1993. Testing the significance of individual and cohort-level covariates in animal survival studies. Pages. 1-17 *In* J. D. Lebreton and P. M. North (editors), The use of marked individuals in the study of bird population dynamics: Models, methods, and software, Birkhauser Verlag, Basel.

Skalski, J. R., S. G. Smith, R. N. Iwamoto, J. G. Williams, and A. Hoffmann. 1998. Use of passive integrated transponder tags to estimate survival of migrant juvenile salmonids in the Snake and Columbia Rivers. Canadian Journal of Fisheries and Aquatic Sciences 55:1484-1493.

Smith, S. G., W. D. Muir, S. Achord, E. E. Hockersmith, B. P. Sandford, J. G. Williams, and J. R. Skalski. 2000a. Survival estimates for the passage of juvenile salmonids through Snake and Columbia River dams and reservoirs, 1998. Report to Bonneville Power

Administration, Contract DE-AI79-93BP10891, 80 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Smith, S. G., W. D. Muir, G. Axel, R. W. Zabel, J. G. Williams, and J. R. Skalski. 2000b. Survival estimates for the passage of juvenile salmonids through Snake and Columbia River dams and reservoirs, 1999. Report to Bonneville Power Administration, Contract DE-AI79-93BP10891, 80 p. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Smith, S. G., W. D. Muir, E. E. Hockersmith, S. Achord, M. B. Eppard, T. E. Ruehle, J. G. Williams, and J. R. Skalski. 1998. Survival estimates for the passage of juvenile salmonids through Snake River dams and reservoirs, 1996. Report to Bonneville Power Administration, Contract DE-AI79-93BP10891, 138 p. plus Appendixes. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Smith, S.G., W.D. Muir, J.G. Williams and J.R. Skalski. In press. Factors associated with travel time and survival of migrant yearling chinook salmon and steelhead in the lower Snake River. North American Journal of Fisheries Management.

Smith, S. G., J. R. Skalski, W. Schlechte, A. Hoffmann, and V. Cassen. 1994. Statistical survival analysis of fish and wildlife tagging studies. SURPH.1 Manual. (Available from Center for Quantitative Science, HR-20, University of Washington, Seattle, WA 98195.)

Williams, J. G., and G. M. Matthews. 1995. A review of flow survival relationships for spring and summer chinook salmon, *Oncorhynchus tshawytscha*, from the Snake River Basin. Fish. Bull., U.S. 93:732-740.

Williams, J. G., S. G. Smith, and W. D. Muir. 2001. Survival estimates for downstream migrant yearling juvenile salmonids through the Snake and Columbia Rivers hydropower system, 1996-1980 and 1993-1999. North American Journal of Fisheries Management 21:310-317.

Vigg, S., and C. C. Burley. 1991. Temperature-dependent maximum daily consumption of juvenile salmonids by northern squawfish (*Ptychocheilus oregonensis*) from the Columbia River. Canadian Journal of Fisheries and Aquatic Sciences 48:2491-2498.

Zabel, R. W., S. G. Smith, W. D. Muir, D. M. Marsh, J. G. Williams, and J. R. Skalski. 2001. Survival estimates for the passage of spring-migrating juvenile salmonids through Snake and Columbia River dams and reservoirs, 2000. Report to Bonneville Power Administration, Contract DE-AI79-93BP10891, 62 electronic pages. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Zabel, R. W., and J. G. Williams. In press. Selective mortality in chinook salmon: what is the role of human disturbance? Ecological Applications.

Zaugg, W. S., and H. H. Wagner. 1973. Gill ATPase activity related to parr-smolt transformation and migration in steelhead trout (Salmo gairdneri): influence of photoperiod and temperature. Comp. Biochem. Physiol. 45B:955-965.

Table 1. Estimated survival probabilities for yearling chinook salmon (hatchery and wild combined) detected and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
06 Apr - 12 Apr	413	0.532 (0.027)	0.846 (0.051)	0.697 (0.070)	0.313 (0.033)
13 Apr - 19 Apr	655	0.936 (0.013)	0.900 (0.027)	0.705 (0.035)	0.594 (0.027)
20 Apr - 26 Apr	2,475	0.956 (0.007)	0.844 (0.013)	0.746 (0.020)	0.602 (0.015)
27 Apr - 03 May	8,834	0.946 (0.005)	0.825 (0.008)	0.740 (0.012)	0.577 (0.009)
04 May - 10 May	3,056	0.880 (0.008)	0.814 (0.015)	0.715 (0.024)	0.512 (0.016)
11 May - 17 May	5,289	0.933 (0.007)	0.754 (0.013)	0.646 (0.018)	0.454 (0.012)
18 May - 24 May	771	0.912 (0.023)	0.603 (0.033)	0.614 (0.065)	0.337 (0.035)
25 May - 31 May	579	0.818 (0.029)	0.640 (0.066)	0.368 (0.061)	0.193 (0.027)
01 Jun - 07 Jun	197	0.772 (0.045)	0.467 (0.119)	0.282 (0.208)	0.102 (0.071)
Weighted mean[a]		**0.939 (0.006)**	**0.820 (0.009)**	**0.720 (0.009)**	**0.551 (0.011)**

[a] Weighted means of the independent estimates for daily groups (31 March - 31 May), with weights inversely proportional to respective estimated relative variances.

Table 2. Estimated survival probabilities for yearling chinook salmon (hatchery and wild combined) detected and released to the tailrace of McNary Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam.

Date at MCN	Number released	MCN to JDA	JDA to BON	MCN to BON
27 Apr - 03 May	359	0.575 (0.076)	0.460 (0.177)	0.265 (0.097)
04 May - 10 May	2,642	0.689 (0.032)	0.747 (0.178)	0.515 (0.121)
11 May - 17 May	9,901	0.722 (0.021)	0.733 (0.087)	0.529 (0.061)
18 May - 24 May	18,902	0.789 (0.024)	0.597 (0.048)	0.471 (0.035)
25 May - 31 May	10,353	0.831 (0.034)	0.688 (0.072)	0.572 (0.055)
01 Jun - 07 Jun	4,052	0.795 (0.054)	0.470 (0.106)	0.374 (0.080)
Weighted mean[a]		**0.758 (0.024)**	**0.645 (0.034)**	**0.501 (0.027)**

a Weighted means of the independent estimates for weekly pooled groups (27 April - 07 June), with weights inversely proportional to respective estimated relative variances.

Table 3. Estimated survival probabilities for hatchery yearling chinook salmon detected and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
06 Apr - 12 Apr	268	0.504 (0.034)	0.821 (0.065)	0.744 (0.104)	0.308 (0.045)
13 Apr - 19 Apr	459	0.923 (0.016)	0.915 (0.033)	0.681 (0.043)	0.575 (0.033)
20 Apr - 26 Apr	1,668	0.955 (0.009)	0.842 (0.017)	0.732 (0.022)	0.588 (0.017)
27 Apr - 03 May	7,136	0.944 (0.005)	0.846 (0.009)	0.741 (0.013)	0.591 (0.010)
04 May - 10 May	2,363	0.883 (0.010)	0.818 (0.018)	0.717 (0.028)	0.518 (0.019)
11 May - 17 May	4,425	0.932 (0.008)	0.770 (0.015)	0.633 (0.020)	0.455 (0.013)
18 May - 24 May	475	0.903 (0.033)	0.619 (0.048)	0.626 (0.101)	0.350 (0.055)
25 May - 31 May	271	0.791 (0.046)	0.699 (0.123)	0.299 (0.076)	0.165 (0.033)
01 Jun - 07 Jun	49	0.680 (0.077)	0.918 (0.683)	0.267 (0.262)	0.167 (0.112)
Weighted mean[a]		**0.933 (0.012)**	**0.831 (0.014)**	**0.716 (0.016)**	**0.554 (0.022)**

[a] Weighted means of the independent estimates for weekly pooled groups (06 April - 07 June), with weights inversely proportional to respective estimated relative variances.

Table 4. Estimated survival probabilities for wild yearling chinook salmon detected and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
06 Apr - 12 Apr	145	0.585 (0.043)	0.883 (0.081)	0.646 (0.094)	0.334 (0.049)
13 Apr - 19 Apr	196	0.966 (0.022)	0.866 (0.045)	0.763 (0.058)	0.638 (0.047)
20 Apr - 26 Apr	807	0.961 (0.011)	0.846 (0.022)	0.790 (0.041)	0.642 (0.033)
27 Apr - 03 May	1,698	0.945 (0.011)	0.744 (0.017)	0.734 (0.026)	0.516 (0.019)
04 May - 10 May	693	0.872 (0.016)	0.803 (0.027)	0.708 (0.044)	0.495 (0.031)
11 May - 17 May	864	0.937 (0.013)	0.692 (0.024)	0.694 (0.040)	0.450 (0.026)
18 May - 24 May	296	0.933 (0.029)	0.588 (0.045)	0.608 (0.078)	0.333 (0.044)
25 May - 31 May	308	0.843 (0.036)	0.601 (0.075)	0.406 (0.086)	0.206 (0.040)
Weighted mean[a]		**0.936 (0.016)**	**0.776 (0.026)**	**0.728 (0.020)**	**0.525 (0.034)**

[a] Weighted means of the independent estimates for weekly pooled groups (06 April - 31 May), with weights inversely proportional to respective estimated relative variances.

Table 5. Estimated survival probabilities for yearling chinook salmon (hatchery and wild combined) detected and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled as necessary to calculate estimates. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
31 Mar - 07 Apr	266	0.351 (0.035)	0.610 (0.091)	0.586 (0.116)	0.125 (0.026)
08 Apr - 10 Apr	151	0.433 (0.043)	0.850 (0.084)	0.646 (0.092)	0.238 (0.039)
11 Apr	69	1.014 (0.043)	0.722 (0.086)	0.768 (0.117)	0.562 (0.086)
12 Apr - 14 Apr	139	0.841 (0.036)	1.084 (0.088)	0.601 (0.088)	0.548 (0.068)
15 Apr	53	0.934 (0.051)	0.913 (0.101)	0.757 (0.166)	0.645 (0.133)
16 Apr	74	0.915 (0.039)	0.896 (0.074)	0.781 (0.120)	0.640 (0.096)
17 Apr	66	0.985 (0.030)	0.883 (0.073)	0.686 (0.083)	0.597 (0.068)
18 Apr	162	0.937 (0.025)	0.885 (0.052)	0.727 (0.069)	0.603 (0.054)
19 Apr	228	0.955 (0.022)	0.869 (0.045)	0.714 (0.063)	0.593 (0.049)
20 Apr	172	0.975 (0.022)	0.889 (0.047)	0.748 (0.072)	0.648 (0.060)
21 Apr	285	0.960 (0.017)	0.942 (0.037)	0.655 (0.049)	0.593 (0.041)
22 Apr	267	0.901 (0.025)	0.836 (0.043)	0.804 (0.065)	0.605 (0.048)
23 Apr	225	0.953 (0.020)	0.852 (0.039)	0.984 (0.094)	0.800 (0.076)
24 Apr	325	0.938 (0.020)	0.858 (0.034)	0.765 (0.053)	0.616 (0.042)
25 Apr	409	0.991 (0.020)	0.803 (0.035)	0.722 (0.044)	0.574 (0.034)
26 Apr	792	0.964 (0.013)	0.809 (0.025)	0.709 (0.035)	0.553 (0.026)
27 Apr	838	0.962 (0.014)	0.837 (0.026)	0.760 (0.041)	0.612 (0.031)
28 Apr	1,857	0.955 (0.011)	0.811 (0.018)	0.751 (0.026)	0.582 (0.019)
29 Apr	2,041	0.944 (0.010)	0.819 (0.017)	0.714 (0.022)	0.552 (0.016)
30 Apr	1,730	0.941 (0.011)	0.817 (0.019)	0.742 (0.029)	0.570 (0.022)
01 May	1,147	0.953 (0.011)	0.871 (0.022)	0.736 (0.030)	0.611 (0.023)
02 May	779	0.951 (0.016)	0.817 (0.027)	0.767 (0.041)	0.595 (0.030)
03 May	442	0.882 (0.023)	0.804 (0.036)	0.745 (0.049)	0.529 (0.034)
04 May	584	0.928 (0.017)	0.820 (0.029)	0.780 (0.051)	0.593 (0.039)
05 May	828	0.813 (0.018)	0.834 (0.032)	0.699 (0.048)	0.474 (0.031)
06 May	283	0.902 (0.030)	0.769 (0.054)	0.662 (0.081)	0.459 (0.054)

Table 5. Continued.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
07 May	103	0.956 (0.049)	0.732 (0.083)	0.608 (0.091)	0.425 (0.060)
08 May	226	0.780 (0.030)	0.868 (0.051)	0.674 (0.076)	0.456 (0.051)
09 May	613	0.949 (0.016)	0.764 (0.032)	0.725 (0.054)	0.525 (0.038)
10 May	419	0.869 (0.021)	0.893 (0.045)	0.712 (0.072)	0.552 (0.051)
11 May	348	0.933 (0.021)	0.834 (0.048)	0.674 (0.064)	0.524 (0.045)
12 May	666	0.932 (0.017)	0.753 (0.029)	0.699 (0.042)	0.491 (0.029)
13 May	369	0.895 (0.022)	0.828 (0.042)	0.726 (0.076)	0.538 (0.054)
14 May	1,233	0.951 (0.014)	0.792 (0.027)	0.667 (0.035)	0.502 (0.024)
15 May	1,263	0.933 (0.016)	0.750 (0.027)	0.637 (0.039)	0.446 (0.026)
16 May	920	0.914 (0.022)	0.697 (0.036)	0.572 (0.046)	0.365 (0.027)
17 May	490	1.024 (0.038)	0.633 (0.047)	0.581 (0.071)	0.377 (0.044)
18 May	201	0.918 (0.041)	0.655 (0.059)	0.622 (0.120)	0.374 (0.072)
19 May	167	0.963 (0.054)	0.668 (0.074)	0.739 (0.199)	0.475 (0.126)
20 May - 21May	170	0.986 (0.046)	0.578 (0.071)	0.414 (0.075)	0.236 (0.040)
22 May	84	0.735 (0.066)	0.640 (0.119)	0.654 (0.193)	0.308 (0.088)
23 May	75	0.795 (0.075)	0.439 (0.112)	0.500 (0.224)	0.175 (0.077)
24 May - May 25	152	0.858 (0.054)	0.585 (0.090)	0.574 (0.149)	0.288 (0.070)
26 May	170	0.884 (0.042)	0.623 (0.088)	0.408 (0.094)	0.225 (0.047)
27 May	132	0.876 (0.091)	0.535 (0.145)	0.370 (0.129)	0.173 (0.047)
28 May - 29 May	138	0.730 (0.048)	0.637 (0.142)	0.412 (0.331)	0.192 (0.149)
30 May	28	0.845 (0.240)	0.482 (0.259)	0.444 (0.314)	0.181 (0.123)
31 May	33	0.691 (0.123)	0.595 (0.282)	0.600 (0.445)	0.247 (0.167)
Weighted mean[a]		**0.939 (0.006)**	**0.820 (0.009)**	**0.720 (0.009)**	**0.551 (0.011)**

[a] Weighted means of the independent estimates for daily groups (31 March - 31 May), with weights inversely proportional to respective estimated relative variances.

Table 6. Estimated detection probabilities for yearling chinook salmon (hatchery and wild combined) detected and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGO	LMO	MCN
06 Apr - 12 Apr	413	0.806 (0.031)	0.664 (0.048)	0.757 (0.067)
13 Apr - 19 Apr	655	0.826 (0.017)	0.660 (0.026)	0.820 (0.033)
20 Apr - 26 Apr	2,475	0.798 (0.010)	0.681 (0.013)	0.788 (0.019)
27 Apr - 03 May	8,834	0.717 (0.006)	0.638 (0.007)	0.762 (0.011)
04 May - 10 May	3,056	0.798 (0.009)	0.642 (0.014)	0.691 (0.022)
11 May - 17 May	5,289	0.739 (0.008)	0.613 (0.011)	0.682 (0.017)
18 May - 24 May	771	0.744 (0.023)	0.698 (0.035)	0.615 (0.063)
25 May - 31 May	579	0.775 (0.030)	0.548 (0.058)	0.662 (0.087)
01 Jun - 07 Jun	197	0.882 (0.046)	0.659 (0.163)	0.500 (0.354)

Table 7. Estimated detection probabilities for yearling chinook salmon (hatchery and wild combined) detected and released tothe tailrace of McNary Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam.

Date at MCN	Number released	JDA	BON
27 Apr - 03 May	359	0.441 (0.065)	0.600 (0.219)
04 May - 10 May	2,642	0.446 (0.023)	0.324 (0.077)
11 May - 17 May	9,901	0.367 (0.012)	0.291 (0.034)
18 May - 24 May	18,902	0.209 (0.007)	0.336 (0.026)
25 May - 31 May	10,353	0.163 (0.008)	0.358 (0.035)
01 Jun - 07 Jun	4,052	0.227 (0.017)	0.394 (0.085)

Table 8. Estimated detection probabilities for hatchery yearling chinook salmon detected and released tothe tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGO	LMO	MCN
06 Apr - 12 Apr	268	0.770 (0.043)	0.668 (0.061)	0.700 (0.095)
13 Apr - 19 Apr	459	0.824 (0.021)	0.662 (0.032)	0.806 (0.041)
20 Apr - 26 Apr	1,668	0.777 (0.012)	0.668 (0.016)	0.814 (0.021)
27 Apr - 03 May	7,136	0.703 (0.007)	0.627 (0.008)	0.758 (0.012)
04 May - 10 May	2,363	0.778 (0.011)	0.618 (0.016)	0.676 (0.025)
11 May - 17 May	4,425	0.712 (0.009)	0.589 (0.013)	0.665 (0.019)
18 May - 24 May	475	0.688 (0.032)	0.647 (0.047)	0.520 (0.084)
25 May - 31 May	271	0.732 (0.047)	0.461 (0.085)	0.800 (0.126)
01 Jun - 07 Jun	49	0.930 (0.069)	0.333 (0.272)	0.500 (0.354)

Table 9. Estimated detection probabilities for wild yearling chinook salmon detected and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGO	LMO	MCN
06 Apr - 12 Apr	145	0.860 (0.043)	0.659 (0.077)	0.832 (0.089)
13 Apr - 19 Apr	196	0.829 (0.031)	0.654 (0.046)	0.849 (0.053)
20 Apr - 26 Apr	807	0.840 (0.015)	0.709 (0.023)	0.726 (0.038)
27 Apr - 03 May	1,698	0.781 (0.013)	0.687 (0.017)	0.782 (0.025)
04 May - 10 May	693	0.867 (0.016)	0.723 (0.027)	0.745 (0.043)
11 May - 17 May	864	0.876 (0.015)	0.734 (0.025)	0.777 (0.040)
18 May - 24 May	296	0.826 (0.032)	0.769 (0.049)	0.754 (0.088)
25 May - 31 May	308	0.809 (0.037)	0.624 (0.077)	0.595 (0.111)

Table 10. Estimated survival probabilities for juvenile steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
06 Apr - 12 Apr	177	0.685 (0.043)	0.712 (0.100)	0.587 (0.282)	0.286 (0.135)
13 Apr - 19 Apr	431	0.754 (0.025)	0.766 (0.071)	0.311 (0.060)	0.179 (0.032)
20 Apr - 26 Apr	2,644	0.892 (0.009)	0.764 (0.025)	0.323 (0.021)	0.220 (0.013)
27 Apr - 03 May	12,557	0.819 (0.005)	0.727 (0.013)	0.279 (0.011)	0.166 (0.006)
04 May - 10 May	9,668	0.768 (0.006)	0.677 (0.014)	0.309 (0.014)	0.161 (0.007)
11 May - 17 May	10,824	0.750 (0.007)	0.673 (0.019)	0.310 (0.021)	0.157 (0.010)
18 May - 24 May	7,979	0.691 (0.012)	0.710 (0.047)	0.170 (0.023)	0.083 (0.010)
25 May - 31 May	2,930	0.593 (0.028)	0.815 (0.197)	0.079 (0.028)	0.038 (0.010)
01 Jun - 07 Jun	1,447	0.553 (0.036)	0.694 (0.192)	0.148 (0.089)	0.057 (0.030)
Weighted mean[a]		**0.801 (0.010)**	**0.709 (0.008)**	**0.296 (0.010)**	**0.168 (0.006)**

[a] Weighted means of the independent estimates for daily groups (31 Mar - 31 May), with weights inversely proportional to respective estimated relative variances.

Table 11. Estimated survival probabilities for juvenile steelhead (hatchery and wild combined) detected and released tothe tailrace of McNary Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam.

Date at MCN	Number released	MCN to JDA	JDA to BON	MCN to BON
04 May - 10 May	181	0.408 (0.063)	0.868 (0.615)	0.354 (0.249)
11 May - 17 May	710	0.311 (0.028)	0.764 (0.213)	0.238 (0.065)
18 May - 24 May	2,034	0.319 (0.037)	0.816 (0.222)	0.260 (0.065)
15 May - 31 May	1,013	0.446 (0.118)	0.498 (0.226)	0.222 (0.082)
Weighted mean[a]		**0.337 (0.025)**	**0.753 (0.063)**	**0.250 (0.016)**

[a] Weighted means of the independent estimates for weekly pooled groups (04 May - 31 May), with weights inversely proportional to respective estimated relative variances.

Table 12. Estimated survival probabilities for juvenile hatchery steelhead detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
06 Apr - 12 Apr	158	0.669 (0.047)	0.773 (0.124)	0.522 (0.253)	0.270 (0.126)
13 Apr - 19 Apr	404	0.739 (0.026)	0.759 (0.072)	0.322 (0.066)	0.181 (0.035)
20 Apr - 26 Apr	2,023	0.879 (0.011)	0.760 (0.028)	0.348 (0.025)	0.233 (0.015)
27 Apr - 03 May	7,235	0.783 (0.008)	0.695 (0.017)	0.300 (0.015)	0.164 (0.008)
04 May - 10 May	6,213	0.741 (0.008)	0.656 (0.019)	0.325 (0.020)	0.158 (0.009)
11 May - 17 May	7,461	0.729 (0.011)	0.752 (0.037)	0.250 (0.025)	0.137 (0.012)
18 May - 24 May	6,339	0.695 (0.015)	0.769 (0.070)	0.152 (0.027)	0.081 (0.012)
25 May - 31 May	2,426	0.602 (0.034)	1.123 (0.388)	0.069 (0.035)	0.046 (0.017)
01 Jun - 07 Jun	1,294	0.566 (0.042)	0.640 (0.188)	0.158 (0.096)	0.057 (0.030)
Weighted mean[a]		**0.773 (0.022)**	**0.706 (0.016)**	**0.306 (0.016)**	**0.170 (0.013)**

[a] Weighted means of the independent estimates for weekly pooled groups (06 April - 07 June), with weights inversely proportional to respective estimated relative variances.

Table 13. Estimated survival probabilities for juvenile wild steelhead detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
20 Apr - 26 Apr	621	0.932 (0.019)	0.768 (0.055)	0.249 (0.042)	0.178 (0.027)
27 Apr - 03 May	5,322	0.870 (0.007)	0.761 (0.020)	0.253 (0.015)	0.167 (0.009)
04 May - 10 May	3,455	0.817 (0.010)	0.708 (0.020)	0.285 (0.018)	0.165 (0.010)
11 May - 17 May	3,363	0.842 (0.009)	0.638 (0.020)	0.367 (0.032)	0.197 (0.016)
18 May - 24 May	1,640	0.716 (0.020)	0.656 (0.058)	0.202 (0.041)	0.095 (0.017)
25 May - 31 May	504	0.588 (0.051)	0.452 (0.124)	0.107 (0.047)	0.028 (0.010)
Weighted mean[a]		**0.850 (0.019)**	**0.710 (0.023)**	**0.282 (0.021)**	**0.168 (0.010)**

[a] Weighted means of the independent estimates for weekly pooled groups (20 April - 31 May), with weights inversely proportional to respective estimated relative variances.

Table 14. Estimated survival probabilities for juvenile steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled as necessary to calculate estimates. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
31 Mar - 11 Apr	81	0.666 (0.064)	0.718 (0.152)	0.670 (0.473)	0.321 (0.223)
12 Apr - 13 Apr	169	0.684 (0.045)	0.739 (0.129)	0.662 (0.507)	0.335 (0.252)
14 Apr - 17 Apr	155	0.805 (0.045)	0.728 (0.127)	0.274 (0.081)	0.160 (0.042)
18 Apr	124	0.719 (0.044)	0.943 (0.148)	0.259 (0.083)	0.175 (0.050)
19 Apr	85	0.804 (0.053)	0.603 (0.086)	0.436 (0.167)	0.211 (0.082)
20 Apr	189	0.867 (0.035)	0.740 (0.085)	0.348 (0.069)	0.223 (0.039)
21 Apr	292	0.828 (0.029)	0.862 (0.082)	0.342 (0.060)	0.244 (0.038)
22 Apr	283	0.875 (0.029)	0.652 (0.055)	0.571 (0.106)	0.326 (0.059)
23 Apr	341	0.880 (0.028)	0.739 (0.074)	0.434 (0.123)	0.283 (0.077)
24 Apr	423	0.899 (0.022)	0.722 (0.058)	0.310 (0.044)	0.201 (0.026)
25 Apr	463	0.954 (0.020)	0.800 (0.057)	0.266 (0.036)	0.203 (0.024)
26 Apr	653	0.889 (0.018)	0.808 (0.065)	0.256 (0.046)	0.184 (0.030)
27 Apr	725	0.900 (0.019)	0.717 (0.046)	0.291 (0.038)	0.188 (0.023)
28 Apr	1,020	0.859 (0.017)	0.709 (0.043)	0.272 (0.034)	0.165 (0.019)
29 Apr	2,086	0.832 (0.012)	0.731 (0.033)	0.227 (0.018)	0.138 (0.010)
30 Apr	1,955	0.812 (0.014)	0.748 (0.033)	0.273 (0.024)	0.166 (0.013)
01 May	2,741	0.798 (0.013)	0.705 (0.027)	0.335 (0.036)	0.189 (0.019)
02 May	2,349	0.795 (0.013)	0.759 (0.032)	0.281 (0.026)	0.170 (0.015)
03 May	1,681	0.814 (0.015)	0.707 (0.032)	0.289 (0.033)	0.166 (0.018)
04 May	1,857	0.801 (0.014)	0.680 (0.028)	0.294 (0.025)	0.160 (0.013)
05 May	1,936	0.780 (0.014)	0.677 (0.029)	0.296 (0.031)	0.156 (0.016)
06 May	1,226	0.771 (0.018)	0.703 (0.041)	0.306 (0.037)	0.166 (0.019)
07 May	482	0.780 (0.026)	0.631 (0.042)	0.376 (0.055)	0.185 (0.027)
08 May	1,328	0.767 (0.017)	0.664 (0.037)	0.295 (0.035)	0.150 (0.017)
09 May	1,574	0.739 (0.015)	0.689 (0.035)	0.357 (0.042)	0.182 (0.020)
10 May	1,265	0.724 (0.018)	0.716 (0.060)	0.263 (0.042)	0.136 (0.019)

Table 14. Continued.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
11 May	1,266	0.711 (0.018)	0.659 (0.047)	0.320 (0.050)	0.150 (0.022)
12 May	1,115	0.752 (0.019)	0.638 (0.052)	0.317 (0.075)	0.152 (0.034)
13 May	1,167	0.741 (0.017)	0.749 (0.056)	0.374 (0.091)	0.208 (0.049)
14 May	1,205	0.781 (0.019)	0.700 (0.046)	0.336 (0.048)	0.184 (0.024)
15 May	2,501	0.772 (0.016)	0.644 (0.041)	0.292 (0.038)	0.145 (0.017)
16 May	2,563	0.771 (0.018)	0.678 (0.047)	0.305 (0.051)	0.159 (0.025)
17 May	1,007	0.733 (0.033)	0.669 (0.081)	0.268 (0.076)	0.131 (0.034)
18 May	2,043	0.763 (0.026)	0.591 (0.054)	0.246 (0.059)	0.111 (0.025)
19 May	1,668	0.695 (0.024)	0.724 (0.096)	0.156 (0.037)	0.079 (0.016)
20 May	1,579	0.657 (0.026)	0.934 (0.201)	0.087 (0.027)	0.053 (0.012)
21 May	567	0.658 (0.047)	0.631 (0.162)	0.200 (0.109)	0.083 (0.040)
22 May	820	0.727 (0.044)	0.770 (0.182)	0.250 (0.153)	0.140 (0.080)
23 May	734	0.618 (0.036)	2.927 (1.958)	0.045 (0.039)	0.081 (0.045)
24 May - 25 May	1,205	0.568 (0.032)	0.798 (0.234)	0.061 (0.023)	0.028 (0.007)
26 May - 31 May	2,293	0.613 (0.036)	0.809 (0.237)	0.114 (0.062)	0.057 (0.026)
Weighted mean[a]		**0.801 (0.010)**	**0.709 (0.008)**	**0.296 (0.010)**	**0.168 (0.006)**

[a] Weighted means of the independent estimates for daily groups (31 March - 31 May), with weights inversely proportional to respective estimated relative variances.

Table 15. Estimated detection probabilities for juvenile steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGO	LMO	MCN
06 Apr - 12 Apr	177	0.834 (0.046)	0.649 (0.095)	0.523 (0.249)
13 Apr - 19 Apr	431	0.874 (0.025)	0.649 (0.063)	0.731 (0.117)
20 Apr - 26 Apr	2,644	0.842 (0.010)	0.651 (0.022)	0.781 (0.040)
27 Apr - 03 May	12,557	0.759 (0.006)	0.663 (0.012)	0.768 (0.024)
04 May - 10 May	9,668	0.782 (0.007)	0.675 (0.014)	0.755 (0.028)
11 May - 17 May	10,824	0.731 (0.008)	0.537 (0.016)	0.579 (0.035)
18 May - 24 May	7,979	0.611 (0.012)	0.376 (0.025)	0.542 (0.065)
25 May - 31 May	2,930	0.517 (0.026)	0.226 (0.055)	0.491 (0.129)
01 Jun - 07 Jun	1,447	0.533 (0.037)	0.288 (0.080)	0.408 (0.220)

Table 16. Estimated detection probabilities for juvenile steelhead (hatchery and wild combined) detected and released tothe tailrace of McNary Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam.

Date at MCN	Number released	JDA	BON
04 May - 10 May	181	0.515 (0.087)	0.500 (0.354)
11 May - 17 May	710	0.526 (0.051)	0.545 (0.150)
18 May - 24 May	2,034	0.176 (0.025)	0.429 (0.108)
15 May - 31 May	1,013	0.095 (0.029)	0.444 (0.166)

Table 17. Estimated detection probabilities for juvenile hatchery steelhead detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGO	LMO	MCN
06 Apr - 12 Apr	158	0.814 (0.051)	0.602 (0.104)	0.526 (0.249)
13 Apr - 19 Apr	404	0.881 (0.025)	0.660 (0.065)	0.711 (0.125)
20 Apr - 26 Apr	2,023	0.848 (0.011)	0.644 (0.025)	0.780 (0.043)
27 Apr - 03 May	7,235	0.736 (0.008)	0.655 (0.016)	0.752 (0.031)
04 May - 10 May	6,213	0.775 (0.009)	0.633 (0.018)	0.710 (0.038)
11 May - 17 May	7,461	0.649 (0.011)	0.409 (0.021)	0.518 (0.045)
18 May - 24 May	6,339	0.579 (0.014)	0.309 (0.028)	0.495 (0.075)
25 May - 31 May	2,426	0.493 (0.030)	0.149 (0.052)	0.393 (0.149)
01 Jun - 07 Jun	1,294	0.520 (0.041)	0.283 (0.083)	0.409 (0.220)

Table 18. Estimated detection probabilities for juvenile wild steelhead detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGO	LMO	MCN
20 Apr - 26 Apr	621	0.822 (0.021)	0.681 (0.050)	0.792 (0.107)
27 Apr - 03 May	5,322	0.786 (0.008)	0.673 (0.018)	0.796 (0.037)
04 May - 10 May	3,455	0.792 (0.010)	0.740 (0.020)	0.834 (0.041)
11 May - 17 May	3,363	0.849 (0.010)	0.699 (0.021)	0.684 (0.055)
18 May - 24 May	1,640	0.695 (0.021)	0.549 (0.049)	0.678 (0.119)
25 May - 31 May	504	0.604 (0.055)	0.563 (0.149)	0.750 (0.217)

Table 19. Estimated survival probabilities for PIT-tagged yearling chinook salmon released from hatcheries in 2001. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: Rel-Release site; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Hatchery	Release site	Number released	Rel to LGR	LGR to LGO	LGO to LMO	LMO to MCN	Rel to MCN
Clearwater	Powell Pond	298	0.664 (0.030)	1.002 (0.043)	0.808 (0.080)	0.602 (0.089)	0.324 (0.043)
Clearwater	Crooked R. Pond	300	0.526 (0.030)	0.946 (0.043)	0.961 (0.087)	0.737 (0.128)	0.352 (0.058)
Clearwater	Lolo Cr.	1,042	0.535 (0.016)	0.952 (0.025)	0.849 (0.042)	0.651 (0.048)	0.282 (0.020)
Clearwater	Newsome Cr.	1,055	0.490 (0.016)	0.959 (0.026)	0.857 (0.045)	0.655 (0.055)	0.263 (0.021)
Dworshak	Dworshak H.	55,142	0.747 (0.002)	0.943 (0.003)	0.838 (0.005)	0.694 (0.007)	0.410 (0.004)
Kooskia	Kooskia H.	749	0.577 (0.019)	0.957 (0.022)	0.830 (0.033)	0.771 (0.051)	0.353 (0.025)
Lookingglass	Imnaha Weir	20,922	0.747 (0.003)	0.962 (0.005)	0.894 (0.008)	0.750 (0.012)	0.481 (0.008)
Lookingglass	Catherine Cr. Pond	20,915	0.519 (0.004)	0.949 (0.008)	0.813 (0.014)	0.663 (0.019)	0.266 (0.007)
Lookingglass	Lostine R. Pond	7,885	0.478 (0.006)	0.950 (0.009)	0.831 (0.016)	0.674 (0.023)	0.255 (0.008)
Lookingglass	Grande Ronde R. Pond	495	0.508 (0.023)	0.944 (0.025)	0.890 (0.053)	0.749 (0.100)	0.320 (0.043)
McCall	Knox Bridge	55,129	0.666 (0.002)	0.934 (0.005)	0.775 (0.008)	0.647 (0.010)	0.312 (0.005)
Pahsimeroi	Pahsimeroi Pond	1,000	0.621 (0.016)	0.974 (0.025)	0.774 (0.049)	0.637 (0.073)	0.298 (0.032)
Rapid River	Rapid River H.	55,091	0.689 (0.002)	0.961 (0.004)	0.855 (0.006)	0.699 (0.008)	0.396 (0.004)
Sawtooth	Sawtooth H.	500	0.524 (0.023)	0.958 (0.025)	0.824 (0.049)	0.632 (0.083)	0.262 (0.035)

Table 20. Estimated survival probabilities for PIT-tagged juvenile steelhead released from hatcheries in 2001. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: Rel-Release site; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Hatchery	Release site	Number released	Rel to LGR	LGR to LGO	LGO to LMO	LMO to MCN	Rel to MCN
Clearwater	Lolo Cr.	300	0.473 (0.030)	0.783 (0.061)	0.566 (0.092)	0.353 (0.104)	0.074 (0.021)
Clearwater	S. F. Clearwater	299	0.660 (0.028)	0.863 (0.036)	0.811 (0.083)	NA	NA
Clearwater	Crooked R. Pond	599	0.500 (0.022)	0.751 (0.048)	0.425 (0.049)	0.391 (0.137)	0.062 (0.022)
Clearwater	Red R. Pond	299	0.706 (0.028)	0.722 (0.052)	0.616 (0.100)	0.246 (0.073)	0.077 (0.021)
Dworshak	Clear Cr.	899	0.775 (0.015)	0.782 (0.023)	0.658 (0.050)	0.265 (0.048)	0.106 (0.018)
Dworshak	Dworshak H.	4,205	0.760 (0.007)	0.757 (0.012)	0.746 (0.027)	0.252 (0.019)	0.108 (0.007)
Dworshak	S. F. Clearwater	900	0.793 (0.014)	0.821 (0.023)	0.709 (0.053)	0.271 (0.048)	0.125 (0.021)
Sawtooth	Squaw Creek Pond	300	0.479 (0.033)	1.726 (1.104)	NA	NA	NA

Table 21. Estimated survival probabilities for PIT-tagged juvenile sockeye salmon from Sawtooth Hatchery in 2001. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: Rel-Release site; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Hatchery	Release site	Number released	Rel to LGR	LGR to LGO	LGO to LMO	LMO to MCN	Rel to MCN
Sawtooth	Alturus L. Cr. (Apr 29)	301	0.370 (0.031)	0.907 (0.119)	0.438 (0.119)	1.286 (1.137)	0.189 (0.164)
Sawtooth	Alturus L. Cr. (May 15)	84	0.393 (0.066)	NA	NA	NA	NA
Sawtooth	Pettit L. Cr. (Apr 29)	143	0.277 (0.054)	0.533 (0.215)	NA	NA	NA
Sawtooth	Pettit L. Cr. (May 15)	130	NA[a]	NA	NA	NA	NA
Sawtooth	Redfish L. Cr.	1,000	0.150 (0.014)	1.292 (0.549)	0.288 (0.174)	0.263 (0.213)	0.015 (0.010)
Sawtooth	Alturus L. Cr. (Apr 29 wild)	164	0.203 (0.039)	0.687 (0.135)	0.525 (0.245)	0.500 (0.382)	0.037 (0.026)

[a] Only 5 fish from this release group were detected at Lower Granite Dam, too few fish to estimate survival.

Table 22. Estimated detection probabilities for PIT-tagged yearling chinook salmon released from hatcheries in 2001. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Hatchery	Release site	Release number	LGR	LGO	LMO	MCN
Clearwater	Powell Pond	298	0.662 (0.036)	0.693 (0.043)	0.531 (0.060)	0.631 (0.082)
Clearwater	Crooked R. Pond	300	0.793 (0.035)	0.635 (0.047)	0.549 (0.061)	0.532 (0.092)
Clearwater	Lolo Cr.	1,042	0.802 (0.018)	0.643 (0.026)	0.557 (0.033)	0.733 (0.046)
Clearwater	Newsome Cr.	1,055	0.805 (0.019)	0.634 (0.027)	0.573 (0.034)	0.678 (0.051)
Dworshak	Dworshak H.	55,142	0.721 (0.002)	0.784 (0.003)	0.665 (0.005)	0.818 (0.007)
Kooskia	Kooskia H.	749	0.718 (0.023)	0.747 (0.025)	0.693 (0.032)	0.745 (0.047)
Lookingglass	Imnaha Weir	20,922	0.713 (0.004)	0.778 (0.005)	0.629 (0.008)	0.735 (0.011)
Lookingglass	Catherine Cr. Pond	20,915	0.710 (0.005)	0.714 (0.007)	0.590 (0.011)	0.647 (0.017)
Lookingglass	Lostine R. Pond	7,885	0.727 (0.008)	0.722 (0.009)	0.583 (0.013)	0.645 (0.020)
Lookingglass	Grande Ronde R. Pond	495	0.784 (0.027)	0.830 (0.029)	0.611 (0.046)	0.642 (0.084)
McCall	Knox Bridge	55,129	0.787 (0.002)	0.702 (0.004)	0.584 (0.006)	0.680 (0.010)
Pahsimeroi	Pahsimeroi Pond	1,000	0.785 (0.018)	0.718 (0.025)	0.516 (0.036)	0.544 (0.059)
Rapid River	Rapid River H.	55,091	0.776 (0.002)	0.711 (0.004)	0.603 (0.005)	0.730 (0.008)
Sawtooth	Sawtooth H.	500	0.752 (0.028)	0.824 (0.029)	0.729 (0.046)	0.589 (0.078)

Table 23. Estimated detection probabilities for PIT-tagged juvenile steelhead released from hatcheries in 2001. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Hatchery	Release site	Release number	LGR	LGO	LMO	MCN
Clearwater	Lolo Cr.	300	0.917 (0.028)	0.752 (0.062)	0.721 (0.107)	0.800 (0.179)
Clearwater	S. F. Clearwater	299	0.912 (0.023)	0.803 (0.039)	0.704 (0.075)	NA
Clearwater	Crooked R. Pond	599	0.909 (0.021)	0.719 (0.049)	0.878 (0.066)	0.623 (0.214)
Clearwater	Red R. Pond	299	0.938 (0.021)	0.722 (0.054)	0.684 (0.107)	0.809 (0.173)
Dworshak	Clear Cr.	899	0.909 (0.013)	0.802 (0.024)	0.730 (0.053)	0.709 (0.111)
Dworshak	Dworshak H.	4,205	0.907 (0.006)	0.741 (0.012)	0.673 (0.025)	0.790 (0.044)
Dworshak	S. F. Clearwater	900	0.928 (0.011)	0.779 (0.024)	0.706 (0.052)	0.663 (0.104)
Sawtooth	Squaw Creek Pond	300	0.932 (0.038)	0.111 (0.074)	NA	NA

Table 24. Estimated detection probabilities for PIT-tagged juvenile sockeye salmon from Sawtooth Hatchery in 2001. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Hatchery	Release site	Release number	LGR	LGO	LMO	MCN
Sawtooth	Alturus L. Cr. (Apr 29)	301	0.744 (0.051)	0.625 (0.090)	0.512 (0.133)	0.167 (0.152)
Sawtooth	Alturus L. Cr. (May 15)	84	0.758 (0.106)	NA	NA	NA
Sawtooth	Pettit L. Cr. (Apr 29)	143	0.708 (0.124)	0.500 (0.204)	NA	NA
Sawtooth	Pettit L. Cr. (May 15)	130	NA[a]	NA	NA	NA
Sawtooth	Redfish L. Cr.	1,000	0.778 (0.057)	0.163 (0.074)	0.387 (0.173)	0.143 (0.132)
Sawtooth	Alturus L. Cr. (Apr 29 wild)	164	0.571 (0.108)	0.875 (0.117)	0.500 (0.250)	0.500 (0.354)

[a] Only 5 fish from this release group were detected at Lower Granite Dam, too few fish to estimate detection probability.

Table 25. Estimated survival probabilities for juvenile salmonids released from fish traps in Snake River Basin in 2001. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: Rel-Release; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Trap	Release dates	Number released	Rel to LGR	LGR to LGO	LGO to LMO	LMO to MCN	Rel to MCN
Hatchery chinook salmon							
Salmon	19 Mar - 01Jun	4,279	0.819 (0.007)	0.942 (0.009)	0.836 (0.015)	0.691 (0.021)	0.445 (0.013)
Snake	27 Apr - 25 May	382	0.956 (0.015)	0.923 (0.027)	0.844 (0.046)	0.747 (0.083)	0.556 (0.059)
Imnaha	23 Mar - 27 Apr	3,008	0.802 (0.008)	0.959 (0.008)	0.900 (0.015)	0.749 (0.022)	0.518 (0.015)
Wild chinook salmon							
Salmon	20 Mar - 08 Jun	1,844	0.875 (0.009)	0.913 (0.012)	0.720 (0.020)	0.632 (0.029)	0.364 (0.017)
Snake	27 Apr - 23 May	30	0.921 (0.058)	0.872 (0.075)	0.850 (0.097)	0.992 (0.202)	0.678 (0.157)
Imnaha	23 Feb - 20 Jun	9,962	0.836 (0.004)	0.944 (0.004)	0.835 (0.008)	0.728 (0.011)	0.480 (0.007)
Pahsimeroi	26 Feb - 31 May	529	0.259 (0.020)	0.778 (0.062)	0.502 (0.073)	0.477 (0.134)	0.048 (0.014)
S. F. Salmon	20 Mar - 14 May	442	0.511 (0.025)	0.877 (0.042)	0.529 (0.067)	0.480 (0.122)	0.114 (0.028)
Sawtooth	21 Mar - 30 May	369	0.643 (0.027)	0.825 (0.042)	0.560 (0.062)	0.441 (0.077)	0.131 (0.023)
Crooked Fork Cr.	20 Mar - 07 May	234	0.525 (0.035)	0.826 (0.055)	0.541 (0.081)	0.405 (0.092)	0.095 (0.022)
Hatchery steelhead							
Salmon	26 Mar - 08 Jun	3,147	0.780 (0.009)	0.676 (0.020)	0.645 (0.050)	0.229 (0.029)	0.078 (0.008)
Snake	27 Apr - 29 May	2,353	0.892 (0.008)	0.691 (0.020)	0.693 (0.058)	0.356 (0.065)	0.152 (0.025)
Imnaha	27 Mar - 25 May	3,297	0.826 (0.008)	0.742 (0.021)	0.683 (0.050)	0.300 (0.044)	0.126 (0.016)

Table 25. Continued

Trap	Release dates	Number released	Rel to LGR	LGR to LGO	LGO to LMO	LMO to MCN	Rel to MCN
Wild steelhead							
Salmon	05 Apr - 08 Jun	478	0.862 (0.020)	0.710 (0.036)	0.634 (0.067)	0.286 (0.062)	0.111 (0.023)
Snake	27 Apr - 29 May	835	0.958 (0.011)	0.818 (0.025)	0.593 (0.037)	0.283 (0.049)	0.131 (0.023)
Imnaha	22 Mar - 25 May	3,572	0.830 (0.007)	0.819 (0.011)	0.719 (0.025)	0.353 (0.031)	0.172 (0.014)
Pahsimeroi	26 Feb - 31 May	429	0.108 (0.016)	0.591 (0.126)	0.597 (0.260)	NA	NA
Sawtooth	14 Apr - 30 May	256	0.170 (0.024)	0.859 (0.163)	0.550 (0.221)	NA	NA
Crooked Fork Cr.	24 Mar - 30 Jun	291	0.482 (0.030)	0.966 (0.040)	0.707 (0.089)	NA	NA
Hatchery sockeye							
Redfish Lake Cr.	24 Apr - 06 Jun	1,389	0.312 (0.014)	0.720 (0.050)	0.530 (0.107)	1.016 (0.946)	0.121 (0.111)
Wild sockeye							
Redfish Lake Cr.	22 Apr - 06 Jun	38	0.553 (0.165)	0.900 (0.718)	NA	NA	NA

Table 26. Estimated detection probabilities for juvenile salmonids released from fish traps in Snake River Basin in 2001. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Trap	Release dates	Number released	LGR	LGO	LMO	MCN
Hatchery chinook salmon						
Salmon	19 Mar - 01Jun	4,279	0.782 (0.008)	0.735 (0.009)	0.613 (0.013)	0.692 (0.020)
Snake	27 Apr - 25 May	382	0.794 (0.023)	0.742 (0.029)	0.618 (0.040)	0.633 (0.069)
Imnaha	23 Mar - 27 Apr	3,008	0.719 (0.010)	0.760 (0.010)	0.633 (0.014)	0.741 (0.020)
Wild chinook salmon						
Salmon	20 Mar - 08 Jun	1,844	0.858 (0.009)	0.835 (0.013)	0.694 (0.020)	0.745 (0.030)
Snake	27 Apr - 23 May	30	0.832 (0.077)	0.947 (0.052)	0.687 (0.116)	0.800 (0.179)
Imnaha	23 Feb - 20 Jun	9,962	0.814 (0.004)	0.822 (0.005)	0.676 (0.008)	0.787 (0.011)
Pahsimeroi	26 Feb - 31 May	529	0.861 (0.036)	0.777 (0.062)	0.831 (0.089)	0.575 (0.163)
S. F. Salmon	20 Mar - 14 May	442	0.810 (0.029)	0.839 (0.041)	0.658 (0.081)	0.674 (0.155)
Sawtooth	21 Mar - 30 May	369	0.852 (0.027)	0.809 (0.042)	0.704 (0.072)	0.841 (0.103)
Crooked Fork Cr.	20 Mar - 07 May	234	0.830 (0.039)	0.864 (0.052)	0.775 (0.100)	0.889 (0.105)
Hatchery steelhead						
Salmon	26 Mar - 08 Jun	3,147	0.914 (0.008)	0.626 (0.020)	0.471 (0.037)	0.744 (0.071)
Snake	27 Apr - 29 May	2,353	0.916 (0.008)	0.675 (0.020)	0.425 (0.037)	0.461 (0.078)
Imnaha	27 Mar - 25 May	3,297	0.899 (0.008)	0.578 (0.018)	0.435 (0.032)	0.565 (0.074)

Table 26. Continued

Trap	Release dates	Number released	LGR	LGO	LMO	MCN
Wild steelhead						
Salmon	05 Apr - 08 Jun	478	0.888 (0.020)	0.721 (0.038)	0.689 (0.069)	0.846 (0.142)
Snake	27 Apr - 29 May	835	0.879 (0.014)	0.737 (0.025)	0.796 (0.043)	0.806 (0.124)
Imnaha	22 Mar - 25 May	3,572	0.891 (0.007)	0.800 (0.011)	0.635 (0.023)	0.716 (0.055)
Pahsimeroi	26 Feb - 31 May	429	0.909 (0.061)	0.650 (0.142)	0.667 (0.272)	NA
Sawtooth	14 Apr - 30 May	256	0.894 (0.058)	0.615 (0.135)	0.458 (0.187)	NA
Crooked Fork Cr.	24 Mar - 30 Jun	291	0.864 (0.031)	0.813 (0.045)	0.742 (0.091)	NA
Hatchery sockeye						
Redfish Lake Cr.	24 Apr - 06 Jun	1,389	0.769 (0.027)	0.697 (0.048)	0.482 (0.098)	0.125 (0.117)
Wild sockeye						
Redfish Lake Cr.	22 Apr - 06 Jun	38	0.524 (0.175)	0.333 (0.272)	NA	NA

Table 27. Travel time statistics for yearling chinook salmon (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam; BON-Bonneville Dam; N-Number of fish on which statistics are based; Med.-Median.

	LGR to LGO (days)				LGO to LMO (days)				LMO to MCN (days)			
Date at LGR	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
06 Apr - 12 Apr	177	10.4	14.9	18.4	92	3.3	5.7	12.0	55	5.3	7.0	11.2
13 Apr - 19 Apr	506	7.1	9.6	12.5	285	2.6	4.0	9.0	195	5.0	6.6	9.2
20 Apr - 26 Apr	1,888	4.4	5.6	8.0	1,076	2.5	5.0	12.4	771	5.0	6.9	10.2
27 Apr - 03 May	5,989	4.3	7.9	12.8	3,138	3.2	5.6	10.2	2,386	4.4	6.0	8.7
04 May - 10 May	2,147	5.9	7.8	10.8	1,115	2.2	4.0	8.4	674	4.1	5.7	8.8
11 May - 17 May	3,644	3.3	4.6	7.4	1,695	2.4	4.2	9.2	945	4.0	5.4	8.5
18 May - 24 May	523	4.8	7.0	11.0	217	2.3	3.5	6.8	108	3.8	5.4	11.8
25 May - 31 May	367	3.4	5.0	12.1	112	2.2	4.2	12.1	39	4.3	6.9	22.7
01 Jun - 07 Jun	134	3.7	6.9	9.4	31	3.1	4.9	16.6	5	9.1	14.2	15.0

	LGR to MCN (days)				LGR to BON (days)			
Date at LGR	N	20%	Med.	80%	N	20%	Med.	80%
06 Apr - 12 Apr	88	23.2	28.5	38.7	25	41.1	51.6	55.0
13 Apr - 19 Apr	299	16.8	22.8	31.4	62	31.8	43.4	47.4
20 Apr - 26 Apr	1,129	15.0	21.0	26.8	232	27.1	36.4	41.4
27 Apr - 03 May	3,772	16.9	20.1	25.2	804	28.5	33.1	37.2
04 May - 10 May	1,050	14.8	18.8	24.7	280	24.6	29.0	33.1
11 May - 17 May	1,558	11.7	15.5	21.1	426	19.0	22.3	28.3
18 May - 24 May	150	11.9	15.8	23.8	24	17.4	20.4	26.6
25 May - 31 May	67	12.2	19.7	30.8	7	19.0	21.5	30.6
01 Jun - 07 Jun	7	22.0	25.4	27.7	0	NA	NA	NA

Table 28. Migration rate statistics for yearling chinook salmon (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam; BON-Bonneville Dam; N-Number of fish observed; Med-Median.

	LGR to LGO (km/day)				LGO to LMO (km/day)				LMO to MCN (km/day)			
Date at LGR	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
06 Apr - 12 Apr	177	3.3	4.0	5.7	92	3.8	8	13.8	55	10.6	17	22.4
13 Apr - 19 Apr	506	4.8	6.3	8.5	285	5.1	11.5	17.8	195	12.9	18	24
20 Apr - 26 Apr	1,888	7.5	10.6	13.6	1,076	3.7	9.2	18.5	771	11.7	17.3	23.7
27 Apr - 03 May	5,989	4.7	7.6	14.0	3,138	4.5	8.2	14.3	2,386	13.7	19.8	27
04 May - 10 May	2,147	5.5	7.7	10.2	1,115	5.4	11.6	20.4	674	13.5	20.7	29
11 May - 17 May	3,644	8.1	13	18.2	1,695	5.0	10.8	19	945	14	22.2	29.8
18 May - 24 May	523	5.5	8.6	12.4	217	6.8	13	20	108	10.1	22	31.1
25 May - 31 May	367	5.0	12	17.8	112	3.8	10.9	20.5	39	5.2	17.2	27.4
01 Jun - 07 Jun	134	6.3	8.7	16.4	31	2.8	9.3	14.8	5	7.9	8.4	13

	LGR to MCN (km/day)				LGR to BON (km/day)			
Date at LGR	N	20%	Med.	80%	N	20%	Med.	80%
06 Apr - 12 Apr	88	5.8	7.9	9.7	25	8.4	8.9	11.2
13 Apr - 19 Apr	299	7.2	9.9	13.4	62	9.7	10.6	14.5
20 Apr - 26 Apr	1,129	8.4	10.7	15	232	11.1	12.7	17
27 Apr - 03 May	3,772	8.9	11.2	13.3	804	12.4	13.9	16.2
04 May - 10 May	1,050	9.1	12	15.2	280	13.9	15.9	18.8
11 May - 17 May	1,558	10.7	14.5	19.3	426	16.3	20.7	24.2
18 May - 24 May	150	9.5	14.3	18.9	24	17.3	22.6	26.6
25 May - 31 May	67	7.3	11.4	18.5	7	15.1	21.4	24.2
01 Jun - 07 Jun	7	8.1	8.9	10.2	0	NA	NA	NA

Table 29. Travel time statistics for yearling chinook salmon (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of McNary Dam in 2001. Abbreviations: MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam; N-Number of fish on which statistics are based; Med.-Median.

	MCN to JDA (days)				JDA to BON (days)				MCN to BON (days)			
Date at MCN	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
27 Apr - 03 May	91	8.7	14.0	21.9	26	1.9	2.2	3.2	57	12.4	16.4	29.6
04 May - 10 May	813	6.9	10.6	20.2	199	2.0	2.3	2.9	441	9.4	13.6	25.2
11 May - 17 May	2,624	5.0	8.2	16.9	563	2.0	2.3	2.7	1,521	8.1	13.8	19.8
18 May - 24 May	3,111	5.3	9.9	17.1	623	2.0	2.2	2.6	2,993	6.9	11.0	15.5
25 May - 31 May	1,402	4.0	6.6	14.2	339	2.0	2.3	2.7	2,118	5.0	6.2	9.2
01 Jun - 07 Jun	731	3.3	5.2	13.9	137	2.1	2.3	2.7	597	5.0	6.1	9.3

Table 30. Migration rate statistics for yearling chinook salmon (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of McNary Dam in 2001. Abbreviations: MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam; N-Number of fish on which statistics are based; Med.-Median.

	MCN to JDA (km/day)				JDA to BON (km/day)				MCN to BON (km/day)			
Date at MCN	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
27 Apr - 03 May	91	5.6	8.8	14.1	26	34.8	51.1	59.2	57	8.0	14.4	19.1
04 May - 10 May	813	6.1	11.6	17.9	199	38.4	48.9	55.4	441	9.3	17.3	25.2
11 May - 17 May	2,624	7.3	15.1	24.8	563	41.7	48.7	55.9	1,521	11.9	17.1	29.0
18 May - 24 May	3,111	7.2	12.4	23.3	623	42.8	50.4	56.8	2,993	15.2	21.5	34.1
25 May - 31 May	1,402	8.7	18.8	30.8	339	42.5	49.3	55.4	2,118	25.5	37.9	47.0
01 Jun - 07 Jun	731	8.8	23.6	37.5	137	42.2	48.3	54.3	597	25.3	38.9	47.5

Table 31. Travel time statistics for juvenile steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam; BON-Bonneville Dam; N-Number of fish on which statistics are based; Med.-Median.

	LGR to LGO (days)				LGO to LMO (days)				LMO to MCN (days)			
Date at LGR	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
06 Apr - 12 Apr	101	6.3	10.2	15.6	42	5.9	9.1	18.1	14	5.8	8.6	12.0
13 Apr - 19 Apr	284	5.3	8.1	11.3	132	4.5	8.8	15.0	35	5.4	8.9	14.9
20 Apr - 26 Apr	1,985	3.0	4.1	6.4	956	3.2	5.6	13.8	273	5.2	8.0	14.4
27 Apr - 03 May	7,808	2.7	4.7	11.4	3,721	2.8	4.7	9.6	999	4.4	6.0	9.8
04 May - 10 May	5,806	3.9	5.8	9.5	2,631	2.2	3.3	5.9	769	4.0	5.1	7.6
11 May - 17 May	5,937	2.5	3.5	5.7	2,148	1.8	2.7	5.8	513	4.1	5.4	9.6
18 May - 24 May	3,369	3.0	4.6	7.1	900	2.2	3.4	7.2	129	4.2	6.7	11.8
25 May - 31 May	899	2.6	4.6	8.9	168	2.0	3.5	9.9	13	5.9	8.6	10.5
01 Jun - 07 Jun	426	2.6	3.8	6.8	85	2.6	4.2	17.5	9	5.5	7.6	9.0

	LGR to MCN (days)				LGR to BON (days)			
Date at LGR	N	20%	Med.	80%	N	20%	Med.	80%
06 Apr - 12 Apr	23	27.4	36.4	43.0	3	61.4	61.9	68.3
13 Apr - 19 Apr	52	19.2	29.6	37.3	10	38.0	48.8	56.8
20 Apr - 26 Apr	421	15.0	23.9	32.8	86	28.4	36.7	45.2
27 Apr - 03 May	1,522	15.1	18.9	27.7	186	25.0	33.0	40.3
04 May - 10 May	1,126	12.3	15.8	22.4	180	21.5	27.9	34.4
11 May - 17 May	939	9.7	14.5	22.9	146	18.8	24.5	32.4
18 May - 24 May	347	12.3	17.8	28.7	45	20.7	28.5	38.6
25 May - 31 May	53	12.3	21.1	27.0	8	22.5	31.4	36.3
01 Jun - 07 Jun	31	12.6	18.1	21.7	3	20.4	22.4	32.2

Table 32. Migration rate statistics for juvenile steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam; BON-Bonneville Dam; N-Number of fish on which statistics are based; Med.-Median.

	LGR to LGO (km/day)				LGO to LMO (km/day)				LMO to MCN (km/day)			
Date at LGR	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
06 Apr - 12 Apr	101	3.8	5.9	9.5	42	2.5	5.1	7.8	14	9.9	13.8	20.6
13 Apr - 19 Apr	284	5.3	7.4	11.3	132	3.1	5.2	10.2	35	8.0	13.3	21.9
20 Apr - 26 Apr	1,985	9.4	14.5	20.3	956	3.3	8.2	14.3	273	8.2	14.8	22.8
27 Apr - 03 May	7,808	5.3	12.8	22.0	3,721	4.8	9.8	16.6	999	12.2	19.8	27.0
04 May - 10 May	5,806	6.3	10.3	15.5	2,631	7.8	14.0	20.8	769	15.7	23.3	29.6
11 May - 17 May	5,937	10.5	17.1	24.3	2,148	8.0	17.2	25.8	513	12.4	21.8	29.0
18 May - 24 May	3,369	8.5	13.0	19.7	900	6.4	13.4	21.3	129	10.1	17.8	28.5
25 May - 31 May	899	6.7	13.1	23.0	168	4.6	13.1	22.7	13	11.3	13.8	20.1
01 Jun - 07 Jun	426	8.8	16.0	22.9	85	2.6	10.8	18.0	9	13.3	15.6	21.6

	LGR to MCN (km/day)				LGR to BON (km/day)			
Date at LGR	N	20%	Med.	80%	N	20%	Med.	80%
06 Apr - 12 Apr	23	5.2	6.2	8.2	3	6.8	7.4	7.5
13 Apr - 19 Apr	52	6.0	7.6	11.7	10	8.1	9.4	12.1
20 Apr - 26 Apr	421	6.9	9.4	15.0	86	10.2	12.6	16.2
27 Apr - 03 May	1,522	8.1	11.9	14.9	186	11.4	14.0	18.4
04 May - 10 May	1,126	10.0	14.3	18.2	180	13.4	16.5	21.5
11 May - 17 May	939	9.8	15.5	23.1	146	14.2	18.8	24.5
18 May - 24 May	347	7.8	12.6	18.3	45	11.9	16.2	22.2
25 May - 31 May	53	8.3	10.7	18.4	8	12.7	14.7	20.5
01 Jun - 07 Jun	31	10.4	12.5	17.9	3	14.3	20.6	22.6

Table 33. Travel time statistics for steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of McNary Dam in 2001. Abbreviations: MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam; N-Number of fish on which statistics are based; Med.-Median.

	MCN to JDA (days)				JDA to BON (days)				MCN to BON (days)			
Date at MCN	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
04 May - 10 May	38	5.7	7.4	11.7	17	2.0	2.8	3.0	32	9.2	12.4	21.2
11 May - 17 May	116	4.6	6.0	9.2	48	2.2	2.6	3.0	92	7.7	10.3	18.9
18 May - 24 May	114	4.4	6.3	13.2	40	2.2	2.5	2.8	227	7.4	11.4	16.4
25 May - 31 May	43	4.0	6.7	20.2	10	2.4	2.5	3.0	100	6.4	8.5	13.6

Table 34. Migration rate statistics for steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of McNary Dam in 2001. Abbreviations: MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam; N-Number of fish on which statistics are based; Med.-Median.

	MCN to JDA (km/day)				JDA to BON (km/day)				MCN to BON (km/day)			
Date at MCN	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
04 May - 10 May	38	10.5	16.5	21.6	17	37.2	40.4	55.9	32	11.1	19.0	25.7
11 May - 17 May	116	13.4	20.6	26.9	48	37.8	43.5	52.1	92	12.5	22.8	30.6
18 May - 24 May	114	9.3	19.6	28.1	40	40.5	45.7	50.4	227	14.4	20.7	31.8
25 May - 31 May	43	6.1	18.3	30.7	10	37.5	44.7	47.7	100	17.4	27.8	36.6

Table 35. Number of PIT-tagged hatchery steelhead released at Lower Granite by day for survival estimates in 2001. Also included are tagging mortalities and lost tags by date.

Release date	Number released	Mortalities	Lost Tags	Release date	Number released	Mortalities	Lost Tags
11 Apr	59	1		09 May	740	1	2
12 Apr	99			10 May	532	1	1
13 Apr	61			11 May	543		3
14 Apr	54			12 May	540	2	2
17 Apr	85			13 May	560		
18 Apr	118			15 May	639		7
19 Apr	75	1		16 May	677	3	1
20 Apr	157			18 May	656	2	2
21 Apr	193			19 May	708	1	4
22 Apr	186			20 May	637		3
23 Apr	254			22 May	368	3	2
24 Apr	241			23 May	404	6	5
25 Apr	243			24 May	368	9	4
26 Apr	219			25 May	351	1	1
27 Apr	215			26 May	371	2	1
28 Apr	209	2	1	30 May	320	5	
29 Apr	230			31 May	308		
01 May	511	15	10	01 Jun	348	2	2
02 May	498		4	02 Jun	325	4	1
03 May	490	1	4	05 Jun	167	3	1
04 May	515		3	06 Jun	57		
05 May	475	1	3	07 Jun	171		1
06 May	533		2	08 Jun	342		3
08 May	691	2	6	09 Jun	341		2

Table 36. Number of PIT-tagged wild steelhead released at Lower Granite by day for survival estimates in 2001. Also included are tagging mortalities and lost tags by date.

Release date	Number released	Mortalities	Lost Tags	Release date	Number released	Mortalities	Lost Tags
11 Apr	0			09 May	166		
12 Apr	0			10 May	149		
13 Apr	0			11 May	135		2
14 Apr	0			12 May	137	1	
17 Apr	0			13 May	121		
18 Apr	0			15 May	159		
19 Apr	0			16 May	123		
20 Apr	0			18 May	144	1	
21 Apr	43			19 May	90	1	1
22 Apr	26			20 May	164	1	
23 Apr	32			22 May	82		
24 Apr	44			23 May	40		
25 Apr	42			24 May	74		
26 Apr	66	1	1	25 May	98	3	
27 Apr	70			26 May	80	1	
28 Apr	71			30 May	50		
29 Apr	55			31 May	66		
01 May	102	3		01 Jun	23		
02 May	138	1	1	02 Jun	42	3	
03 May	145	1	1	05 Jun	17		
04 May	122		1	06 Jun	1		
05 May	160		1	07 Jun	21		
06 May	105		1	08 Jun	55		
08 May	211			09 Jun	56	1	

Table 37. Regression results for yearling chinook salmon per-project survival versus flow based on the equation Survival = a · Flow^b for several periods of years. Parameter estimates are provided with standard errors in parentheses. The *P*-value corresponds the *b* parameter (i.e., the effects coefficient).

Period	a (s.e.)	b (s.e.)	*P*-value	R^2
1973 - 1979	16.59 (19.03)	0.311 (0.246)	0.135	0.272
1973-1979, 1993-2001	29.47 (20.29)	0.220 (0.149)	0.082	0.154
1993 - 2000	90.13 (24.87)	0.0018 (0.0591)	0.489	0.000
1993 - 2001	76.09 (17.75)	0.037 (0.051)	0.481	0.074

Table 38. Estimated survival probabilities for separate yearling chinook salmon stocks detected and released to the tailrace of McNary Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Release groups that primarily passed John Day during the spill period are in bold. Abbreviations: MCN - McNary Dam; JDA - John Day Dam; SP - spring chinook salmon; S-F - summer-fall chinook salmon.

Date at MCN	Snake River		Upper Columbia R. (SP)		Yakima River		Upper Columbia R. (S-F)	
	Number released	MCN to JDA Survival	Number released	MCN to JDA Survival	Number released	MCN to JDA Survival	Number released	MCN to JDA Survival
12 Apr - Apr 18					76	0.452 (0.089)		
19 Apr - Apr 25					487	0.597 (0.066)	19	0.711 (0.276)
26 Apr - 02 May	205	0.698 (0.175)			845	0.656 (0.058)	1,316	0.872 (0.084)
03 May - 09 May	2,179	0.664 (0.033)	125	0.741 (0.182)	1,693	0.725 (0.046)	6,559	0.861 (0.034)
10 May - 16 May	8,317	0.729 (0.022)	573	0.729 (0.070)	2,253	0.769 (0.041)	11,651	0.834 (0.026)
17 May - 23 May	**18,071**	**0.755 (0.023)**	**1,216**	**0.751 (0.068)**	**2,044**	**0.807 (0.055)**	**19,535**	**0.917 (0.029)**
24 May - 30 May	**11,455**	**0.784 (0.029)**	**2,297**	**0.962 (0.075)**	**1,694**	**0.856 (0.066)**	**19,147**	**0.888 (0.031)**
31 May - 06 Jun	**5,745**	**0.982 (0.063)**	**609**	**0.775 (0.114)**	**1,148**	**0.742 (0.069)**	**6,506**	**0.929 (0.074)**
07 Jun - 13 Jun	1,325	0.661 (0.086)	63	0.370 (0.134)	120	0.850 (0.341)	3,019	0.679 (0.053)
14 Jun - 20 Jun	595	0.360 (0.034)	16	0.469 (0.194)			1,834	0.684 (0.071)
21 Jun - 27 Jun	210	0.200 (0.141)					621	0.667 (0.134)
							463	0.688 (0.210)
							191	0.424 (0.342)

Table 39. Estimated detection probabilities at John Day Dam for separate yearling chinook salmon stocks detected and released to the tailrace of McNary Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Release groups that primarily passed John Day during the spill period are in bold. Abbreviations: JDA - John Day Dam; SP - spring chinook salmon; S-F - summer-fall chinook salmon.

	Snake River		Upper Columbia R. (SP)		Yakima River		Upper Columbia R. (S-F)[1]	
Date at MCN	Number released	JDA Detection	Number released	JDA Detection	Number released	JDA Detection	Number released	JDA Detection
12 Apr - Apr 18					76	0.727 (0.134)		
19 Apr - Apr 25					487	0.440 (0.054)	19	0.711 (0.276)
26 Apr - 02 May	205	0.321 (0.088)			845	0.426 (0.042)	1,316	0.872 (0.084)
03 May - 09 May	2,179	0.450 (0.025)	125	0.421 (0.113)	1,693	0.415 (0.029)	6,559	0.861 (0.034)
10 May - 16 May	8,317	0.393 (0.013)	573	0.440 (0.048)	2,253	0.381 (0.023)	11,651	0.834 (0.026)
17 May - 23 May	**18,071**	**0.231 (0.008)**	**1,216**	**0.299 (0.031)**	**2,044**	**0.290 (0.023)**	**19,535**	**0.917 (0.029)**
24 May - 30 May	**11,455**	**0.177 (0.008)**	**2,297**	**0.203 (0.018)**	**1,694**	**0.234 (0.021)**	**19,147**	**0.888 (0.031)**
31 May - 06 Jun	**5,745**	**0.163 (0.012)**	**609**	**0.276 (0.045)**	**1,148**	**0.323 (0.034)**	**6,506**	**0.929 (0.074)**
07 May - 13 Jun	1,325	0.237 (0.034)	63	0.600 (0.219)	120	0.235 (0.103)	3,019	0.679 (0.053)
14 May - 20 Jun	595	0.756 (0.064)	16	0.667 (0.272)			1,834	0.684 (0.071)
21 May - 27 Jun	210	0.500 (0.354)					621	0.667 (0.134)
							463	0.688 (0.210)
							191	0.424 (0.342)

[1] The weekly periods for the upper Columbia River summer-fall chinook were three days earlier than the other groups because they had shorter travel times through the McNary to John Day Dam reach.

Table 40. Results from the Spill analysis. Survival estimates (with standard errors in parentheses) are provided spill block. The details of the hypothesis testing are provided in the text. Abbreviations: MCN - McNary Dam; JDA - John Day Dam; H1 - hypothesis 1; H2 - hypothesis 2; SP - spring chinook salmon; S-F - summer-fall chinook salmon.

		Survival Estimates (Standard Errors)			*P*-values		
Stock	Reach	Pre-Spill	Spill	Post-Spill	H1	H2	Conclusion
Snake R. Chinook	MCN-JDA	0.712 (0.018)	0.805 (0.018)	0.514 (0.045)	<0.001	0.001	All different
U. Columbia Chinook (SP)	MCN-JDA	0.726 (0.064)	0.868 (0.048)	0.390 (0.107)	0.047	0.080	Spill different
U. Columbia Chinook (S-F)	MCN-JDA	0.845 (0.020)	0.904 (0.020)	0.680 (0.041)	0.004	0.001	All different
Yakima R. Chinook	MCN-JDA	0.716 (0.025)	0.817 (0.037)	0.539 (0.110)	0.014	0.213	Spill different
Snake R. Steelhead	MCN-JDA	0.312 (0.023)	0.371 (0.055)	0.130 (0.060)	0.253		No spill effect
Snake R. Chinook	LMO-MCN	0.732 (0.004)	0.652 (0.007)	0.166 (0.023)	<0.001	<0.001	All different
Snake R. Steelhead	LMO-MCN	0.311 (0.008)	0.218 (0.014)	NA	<0.001	<0.001	All different
U. Columbia Chinook (S-F)	JDA-BON	0.304 (0.152)	0.817 (0.095)	NA	0.017	NA	Spill different
Yakima R. Chinook	JDA-BON	0.549 (0.272)	0.592 (0.088)	NA	0.310	NA	No spill effect

Table 41. Survival estimates (with standard errors in parentheses) from point of release to Bonneville for a variety of spring-migrating salmonid stocks. For each reach, the survival estimate represents a weighed average of daily or weekly estimates (some of which are presented in other tables in this document). In some cases, fish from separate release sites were pooled at downstream so survival estimates were identical. Abbreviations: RLS-release site; MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam; SP-spring chinook salmon; S-F-summer-fall chinook salmon.

Stock	Release Location	Survival Estimates (standard errors)			
		RLS - MCN	MCN - JDA	JDA - BON	RLS - BON
Snake R. Chinook	Lower Granite Dam	0.551 (0.011)	0.758 (0.024)	0.645 (0.034)	0.276 (0.016)
U. Columbia Chinook (SP)	Leavenworth H.	0.500 (0.008)	0.812 (0.051)	0.788 (0.264)	0.335 (0.084)
U. Columbia Chinook (SP)	Winthrop H.	0.427 (0.009)	0.812 (0.051)	0.788 (0.264)	0.286 (0.072)
U. Columbia Chinook (S-F)	Rock Island Dam	0.747 (0.010)	0.863 (0.018)	0.787 (0.067)	0.523 (0.050)
U. Columbia Chinook (S-F)	Rocky Reach Dam	0.695 (0.009)	0.863 (0.018)	0.787 (0.067)	0.487 (0.046)
Yakima R. Chinook	Several Locations	NA[1]	0.743 (0.029)	0.607 (0.080)	NA
Snake R. Steelhead	Lower Granite Dam	0.168 (0.006)	0.337 (0.025)	0.753 (0.063)	0.042 (0.003)

[1] Fish were released at numerous locations in the Yakima River basin. Single point of release to McNary survival estimate not possible.

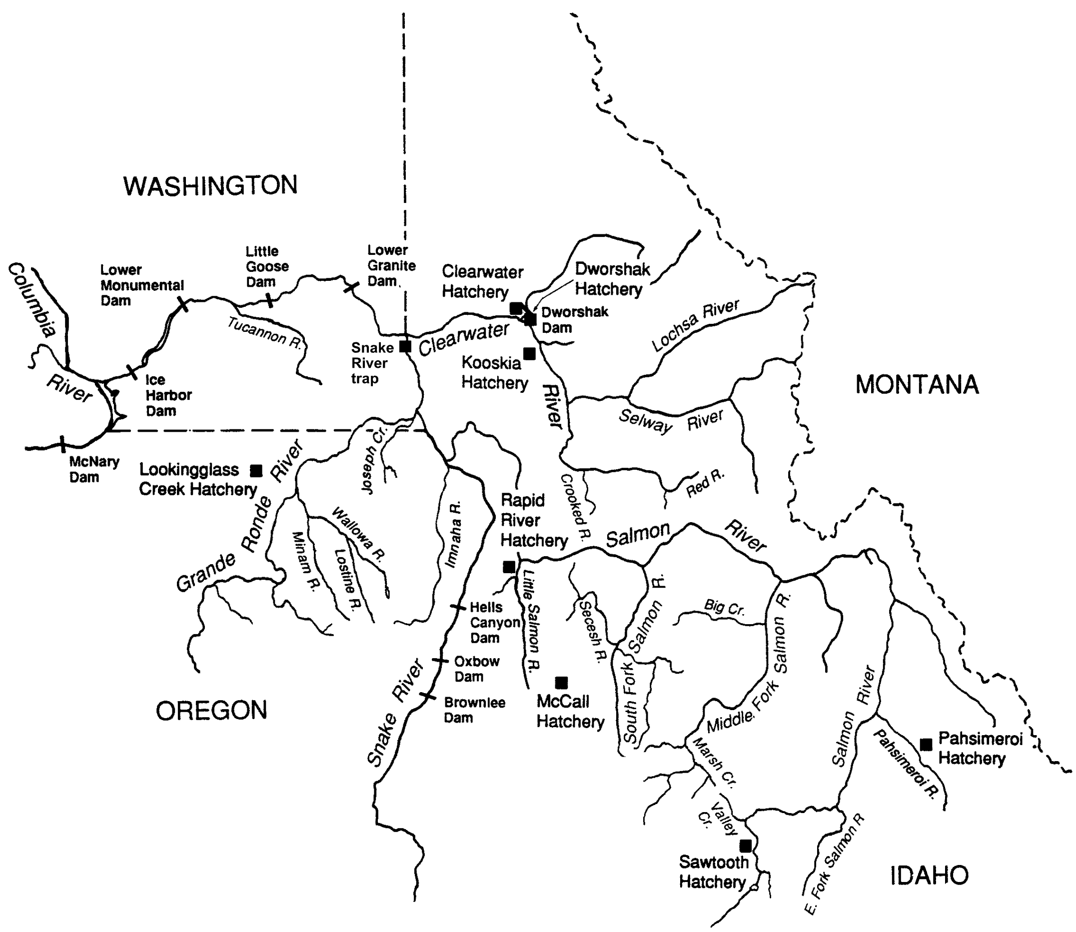

Figure 1. Study area showing release and detection sites on the Snake River.

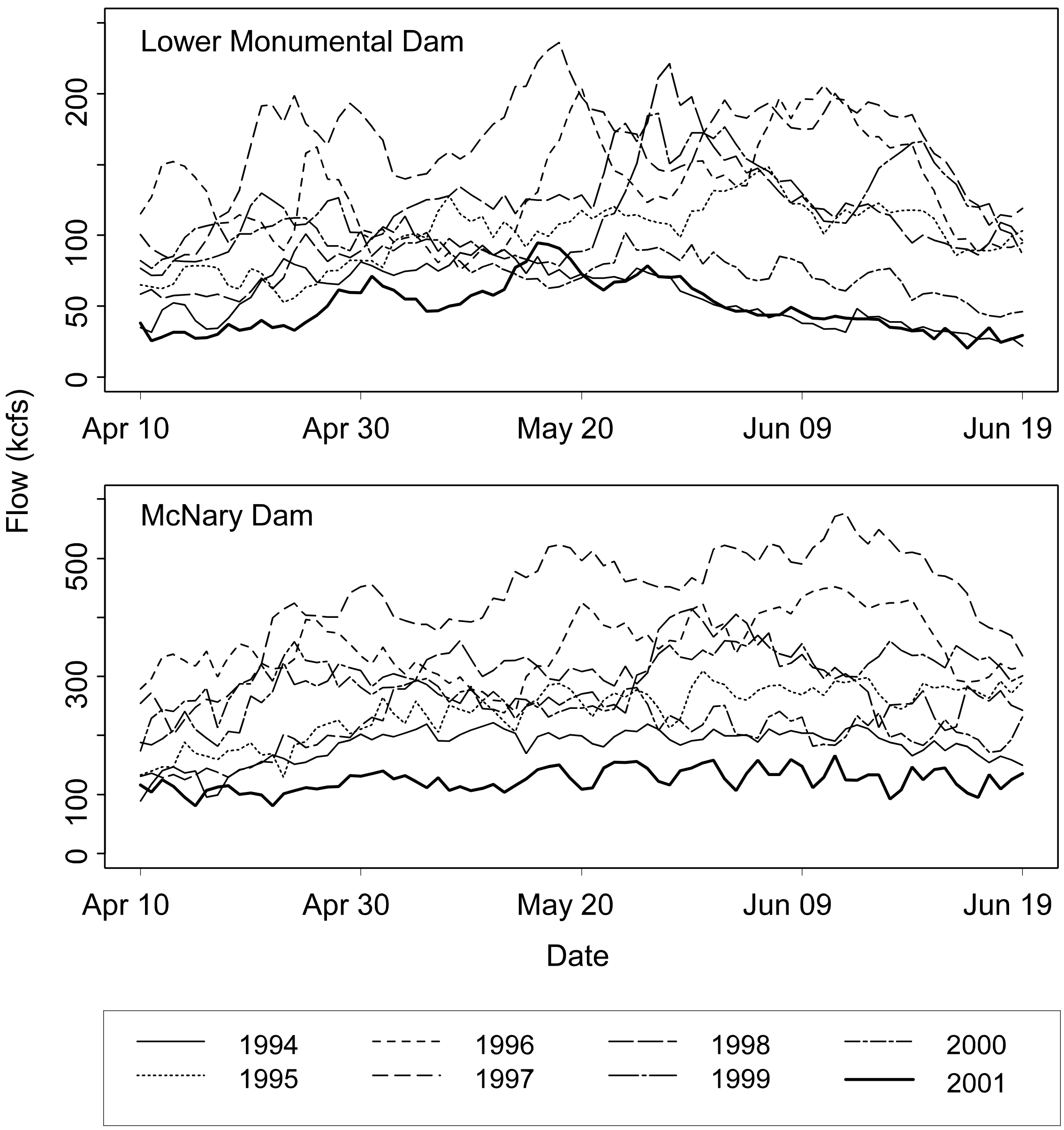

Figure 2. Daily flow level (kcfs) at Lower Monumental and McNary Dams, 1994-2001.

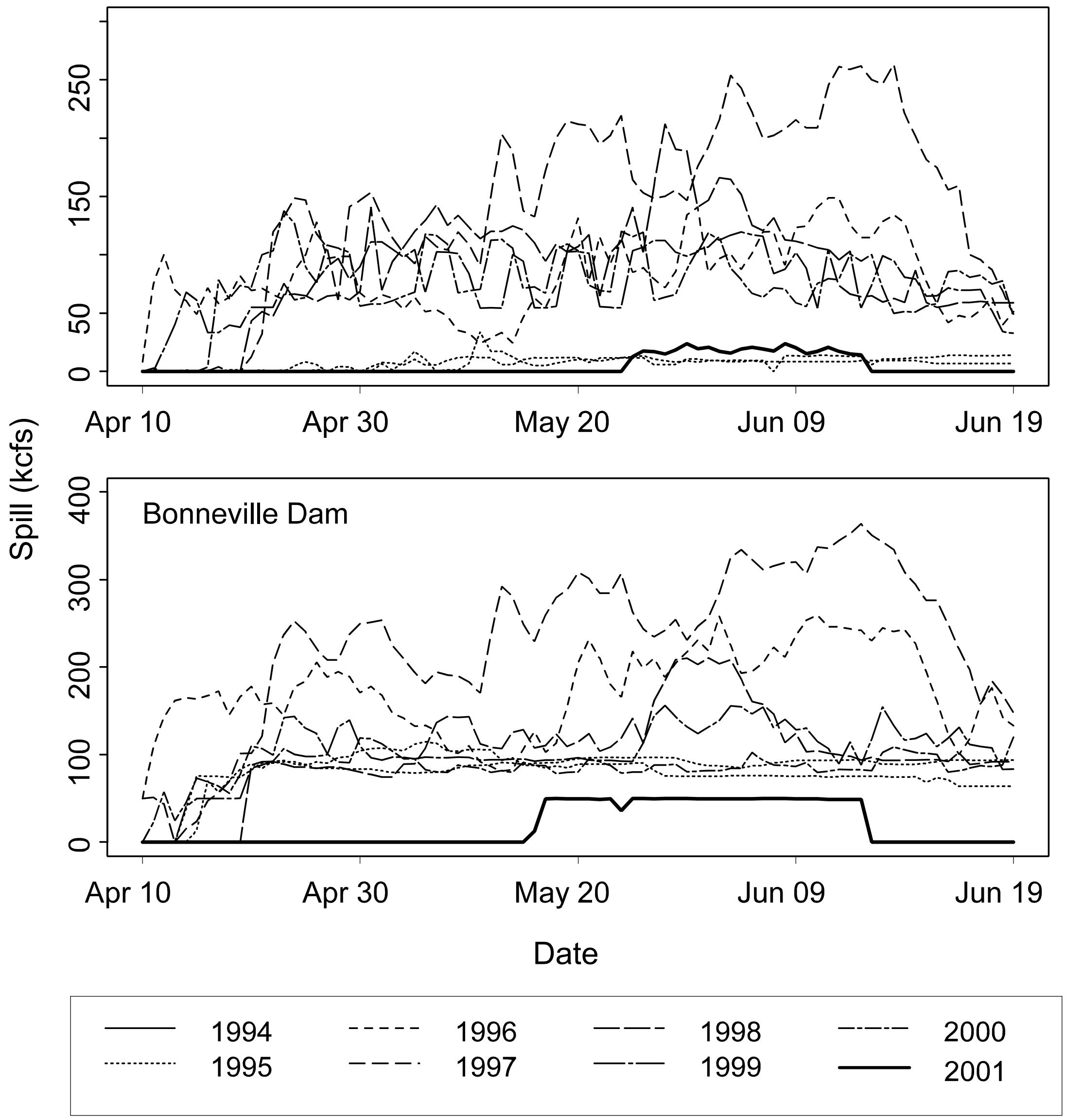

Figure 3. Daily spill level (kcfs) at John Day and Bonneville Dams, 1995-2001. Spill patterns at McNary Dam were similar to those at John Day Dam in 2001. Spill patterns at the Dalles Dam were similar to those at Bonneville Dam in 2001. No spill occurred at the Snake River dams in 2001 during the spring migration period.

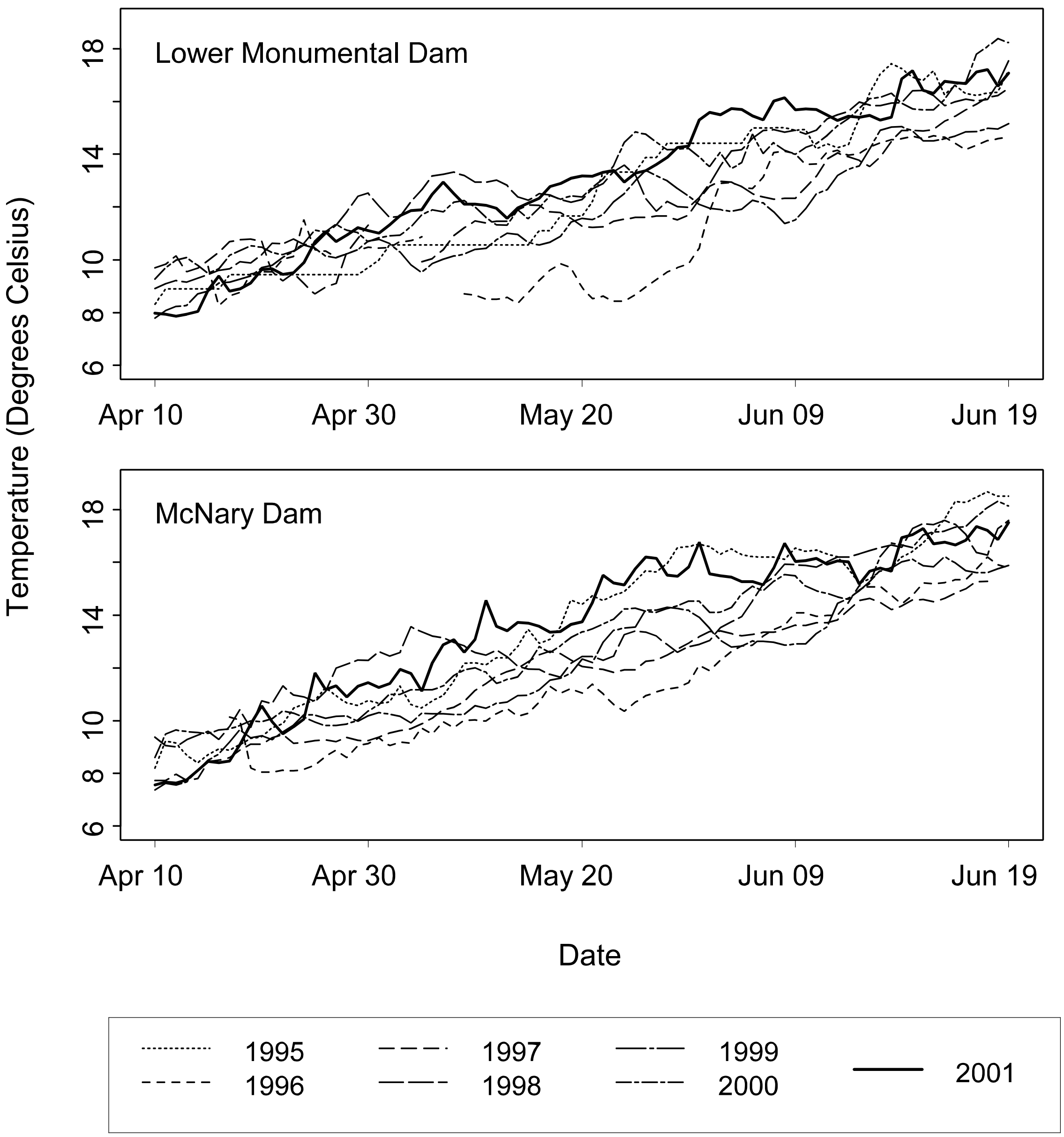

Figure 4. Daily temperature (degrees Celsius) at Lower Monumental and McNary Dams, 1995-2001.

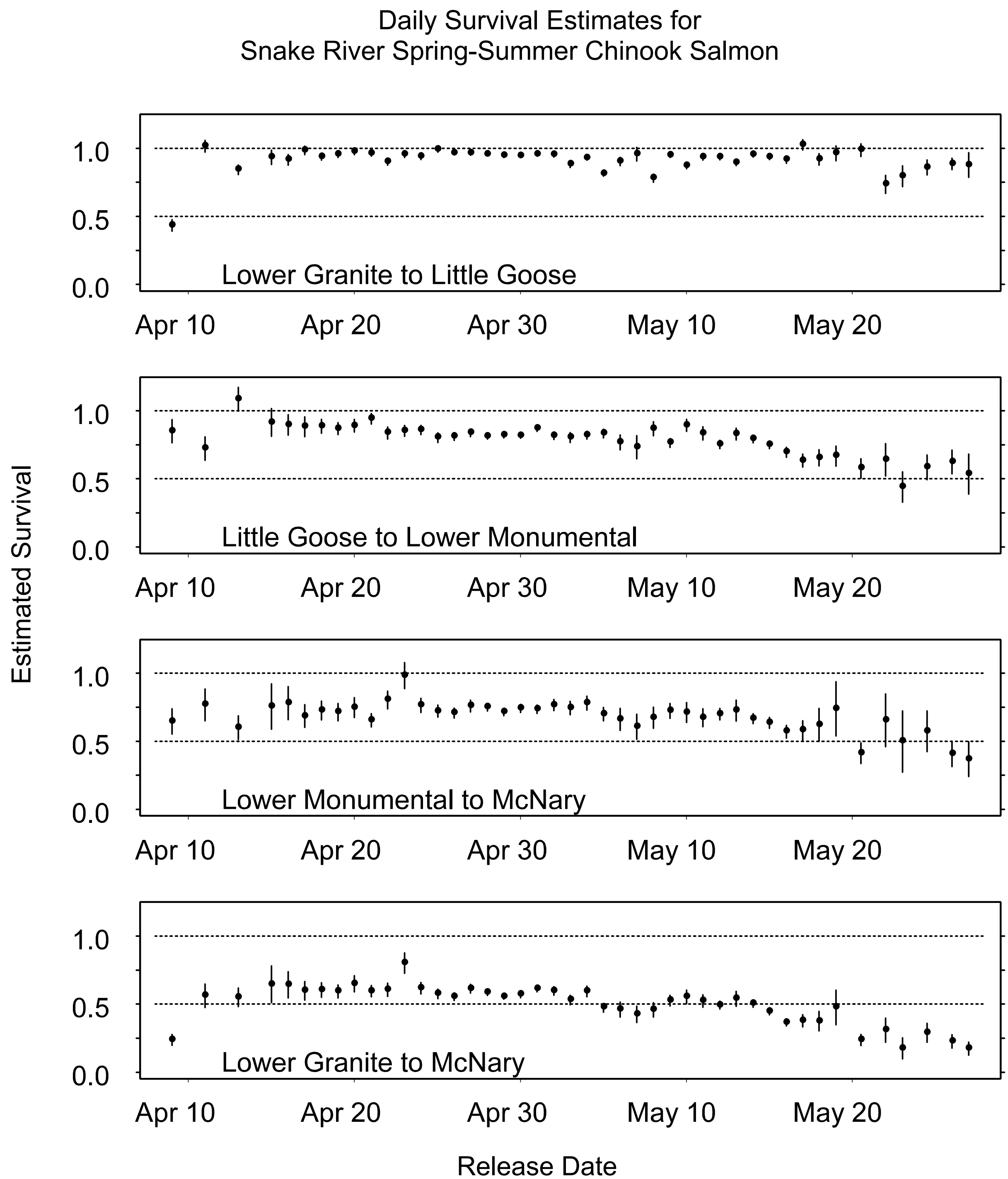

Figure 5. Estimated daily survival versus release date at Lower Granite Dam for Snake River spring-summer chinook salmon. The vertical bars represent +/- one standard error.

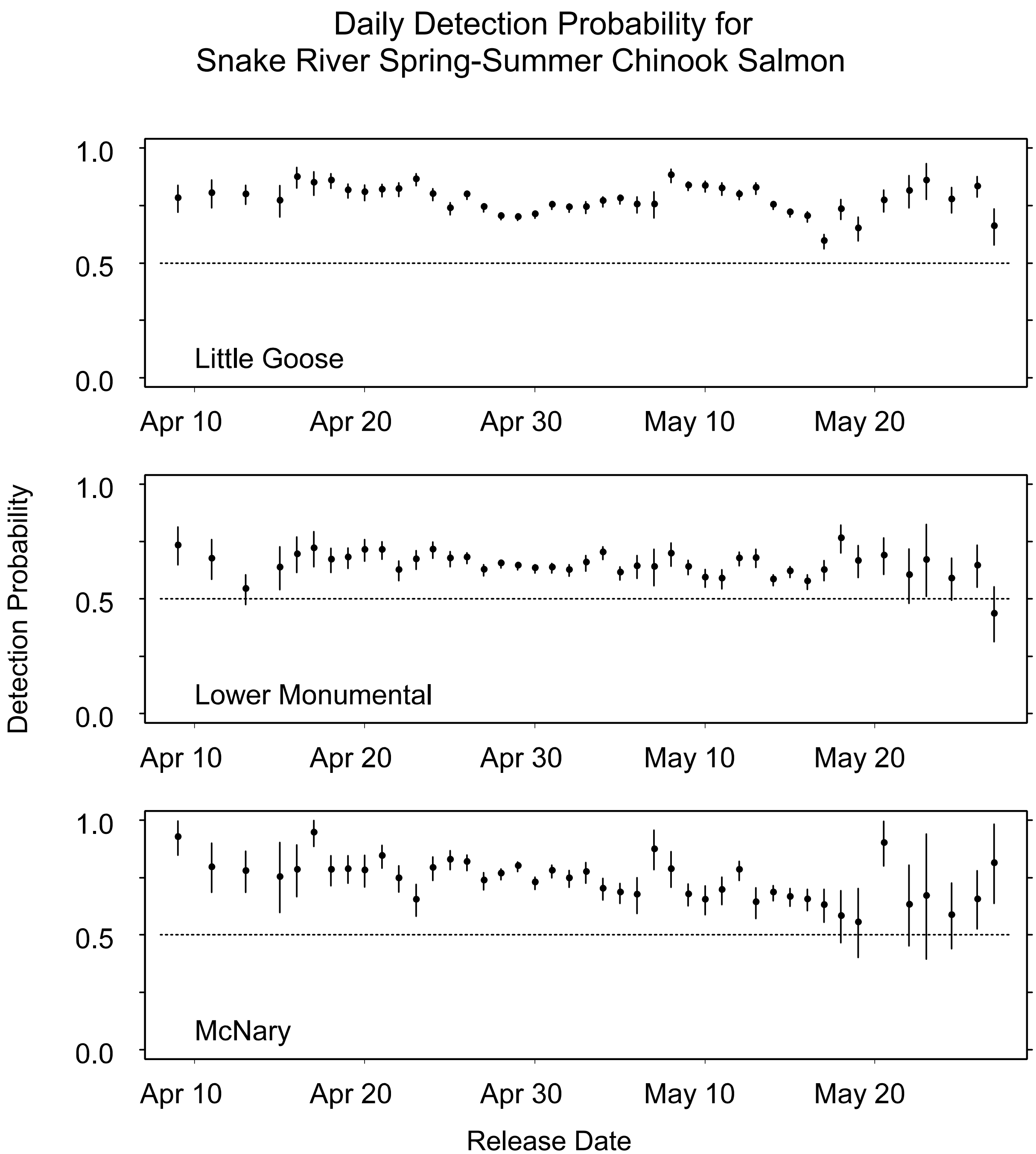

Figure 6. Estimated detection probability versus release date at Lower Granite Dam for Snake River spring-summer chinook salmon. The vertical bars represent +/- one standard error.

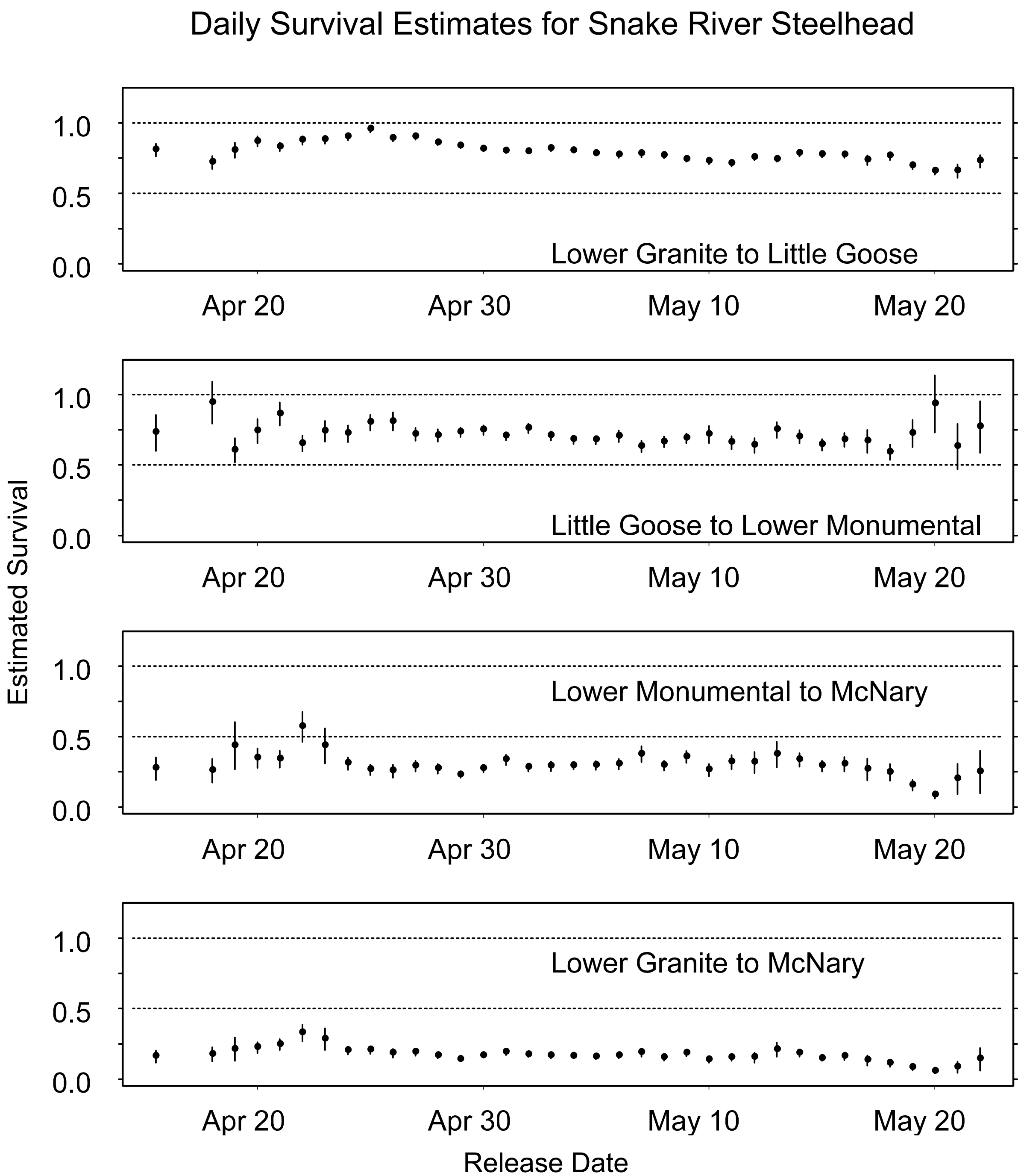

Figure 7. Daily survival estimate versus release date at Lower Granite Dam for Snake River steelhead. The vertical bars represent +/- one standard error.

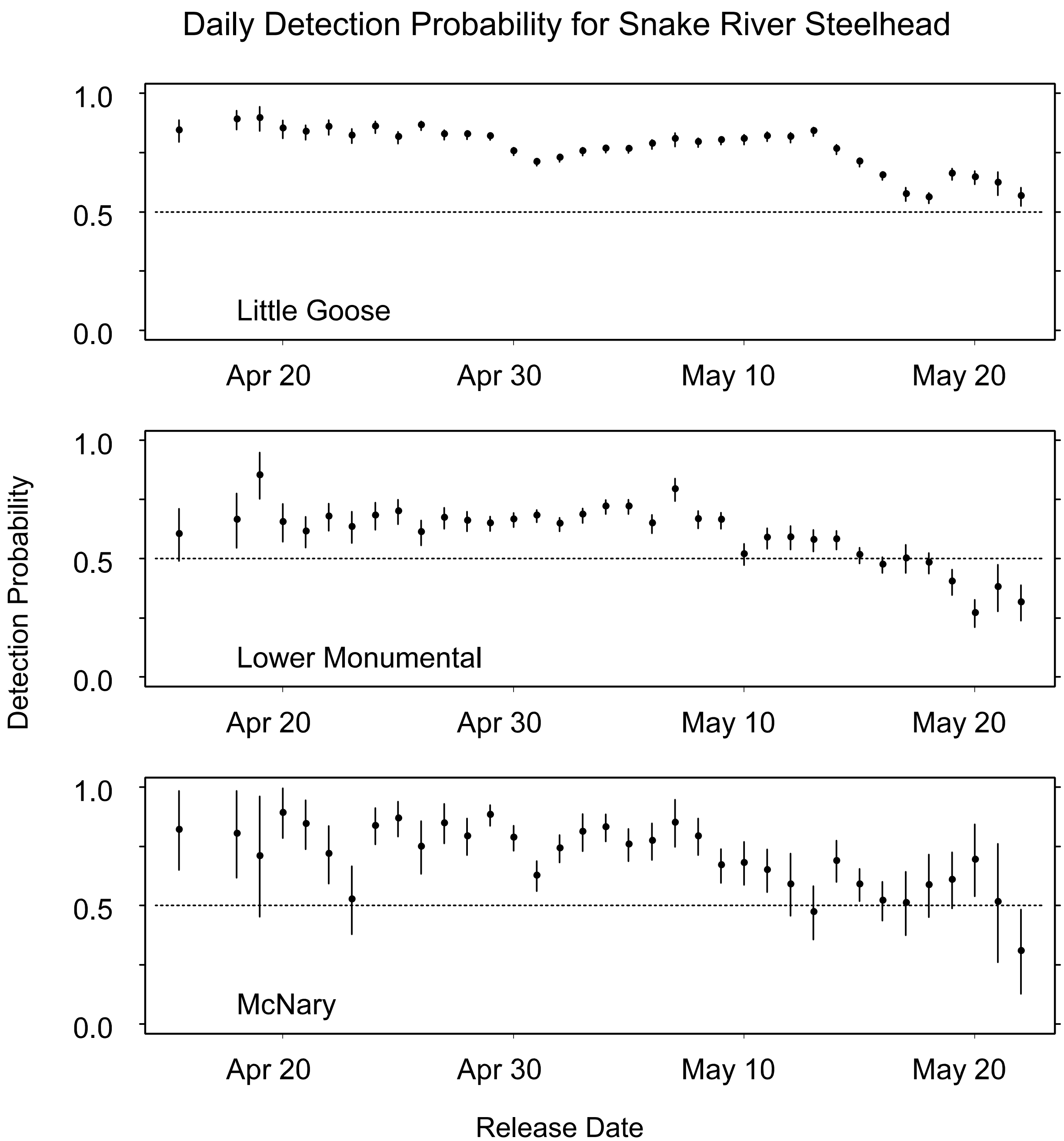

Figure 8. Estimated detection probability versus release date at Lower Granite Dam for Snake River steelhead. The vertical bars represent +/- one standard error.

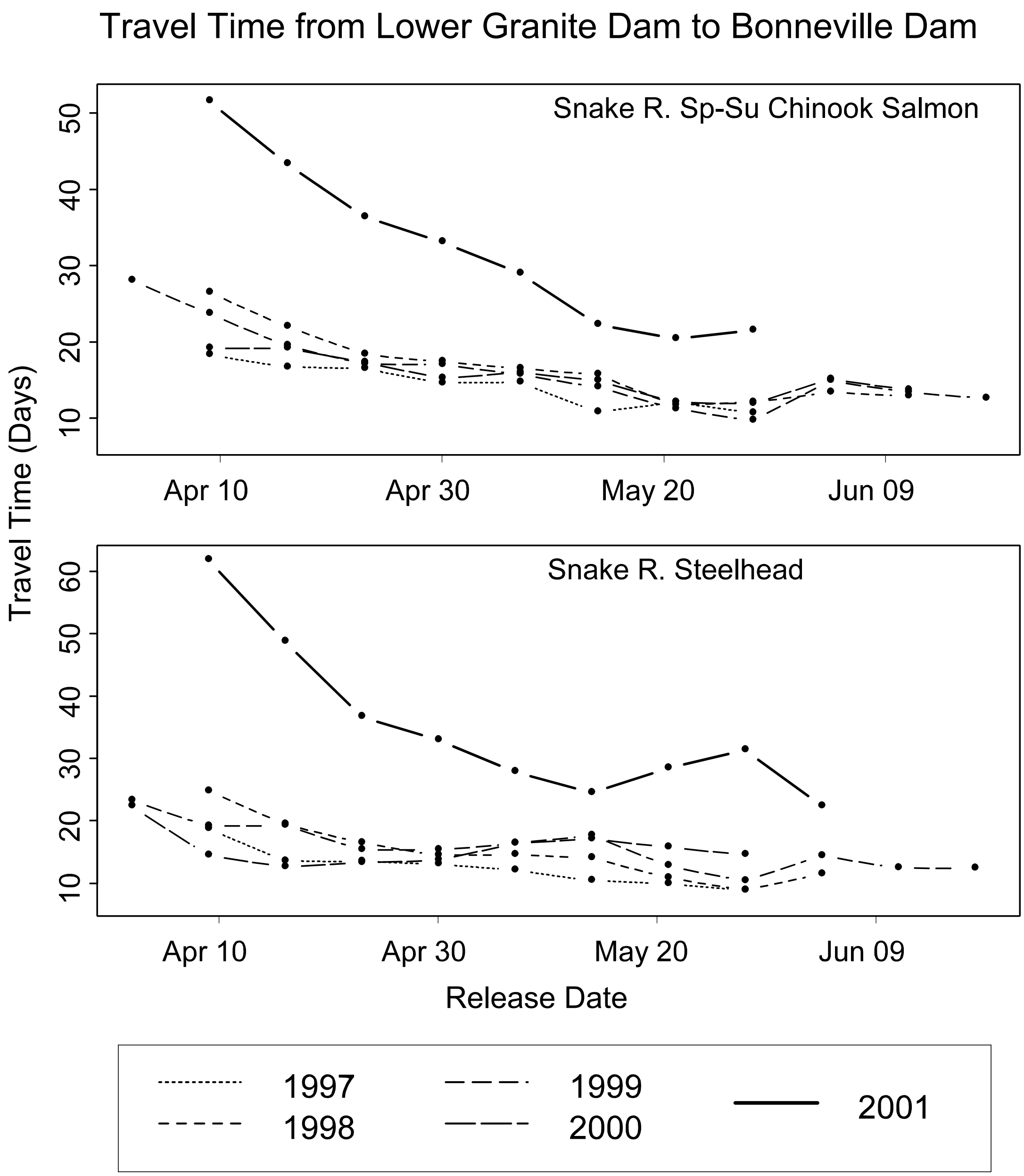

Figure 9. Median travel time (days) from Lower Granite Dam to Bonneville Dam for weekly release groups, 1997-2001.

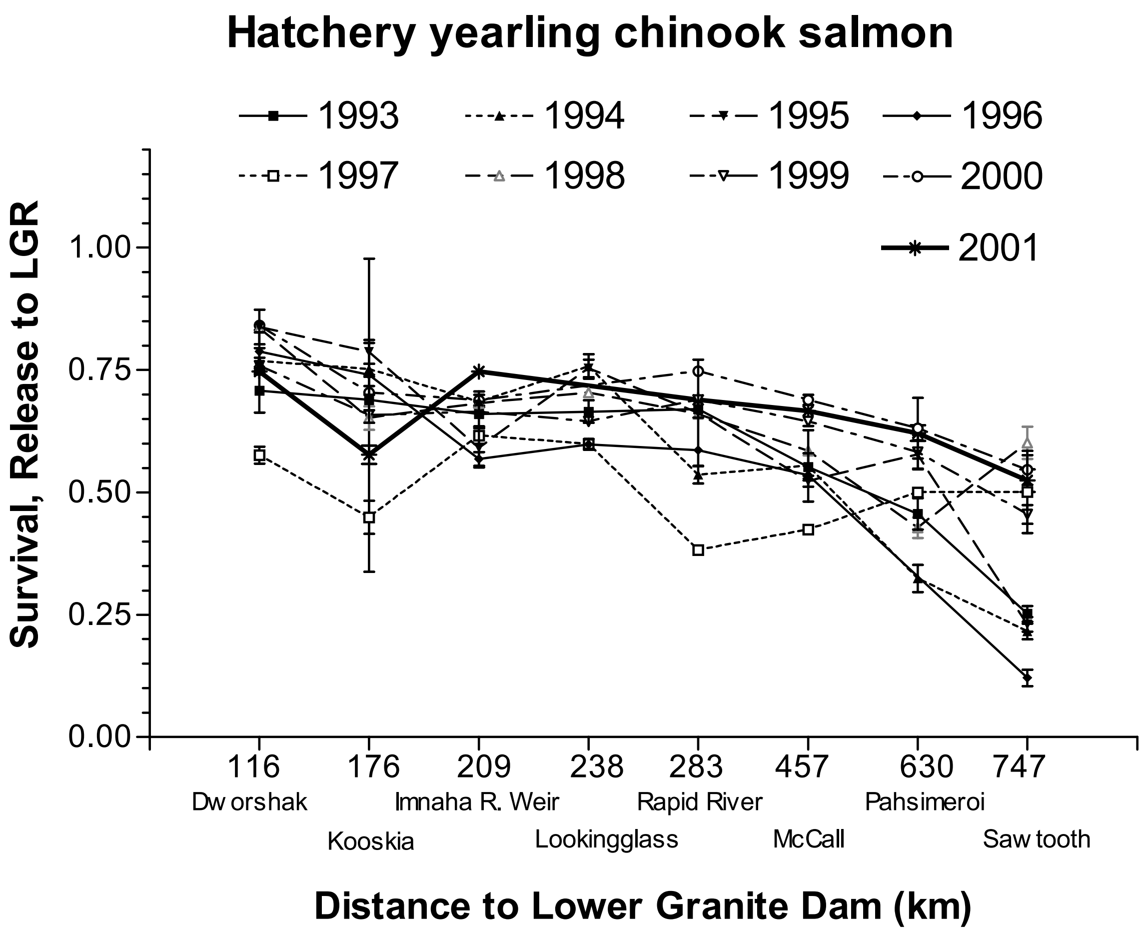

Figure 10. Estimated survival to Lower Granite Dam (LGR) tailrace for PIT-tagged yearling chinook salmon released from Snake River Basin hatcheries. Distance from release to Lower Granite Dam (km) and standard errors also shown.

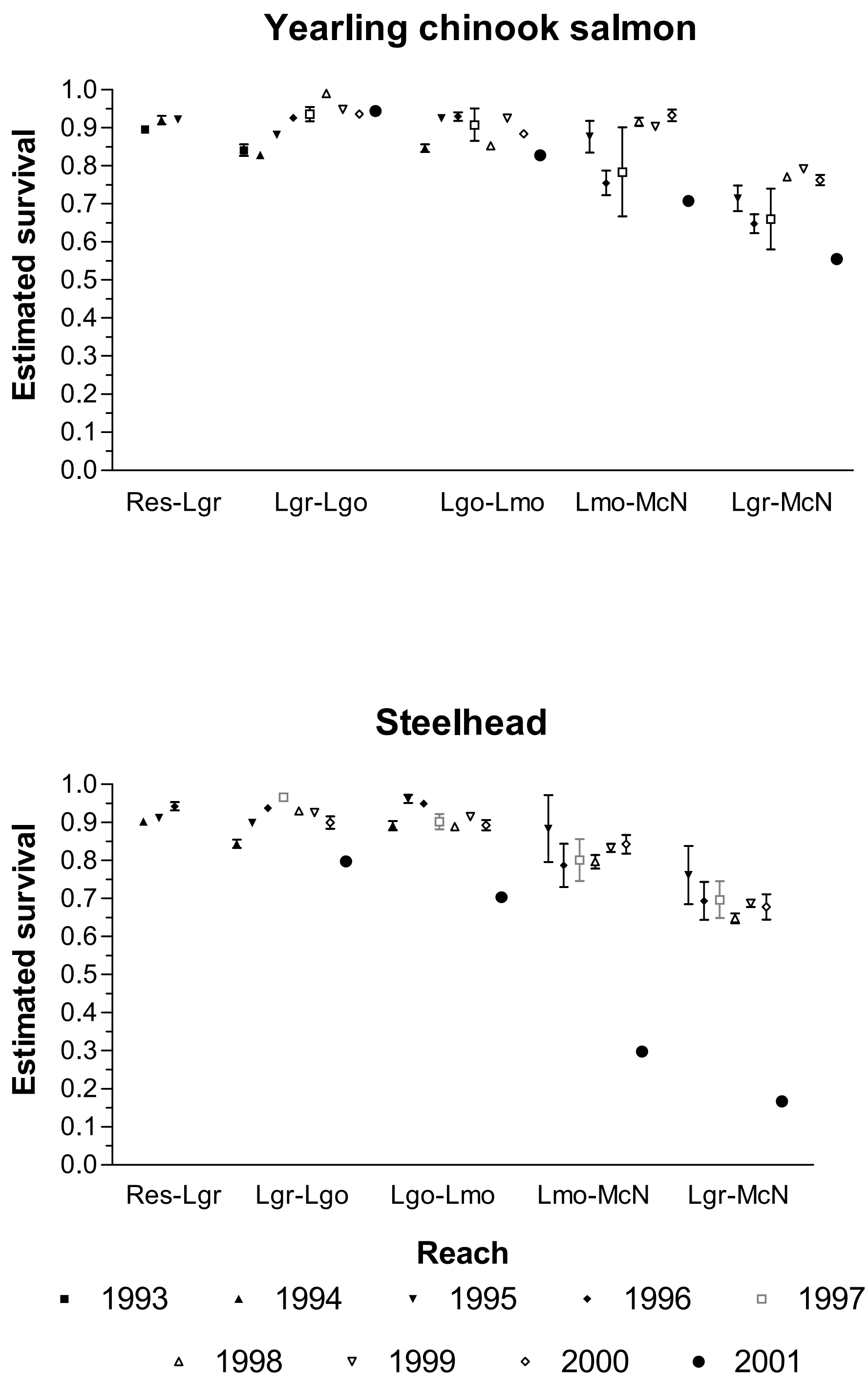

Figure 11. Annual average survival estimates for PIT-tagged yearling chinook salmon and steelhead from Lower Granite Reservoir (RES) to Lower Granite Dam (LGR), to Little Goose Dam (LGO), to Lower Monumental Dam (LMO), and to McNary Dam (MCN).

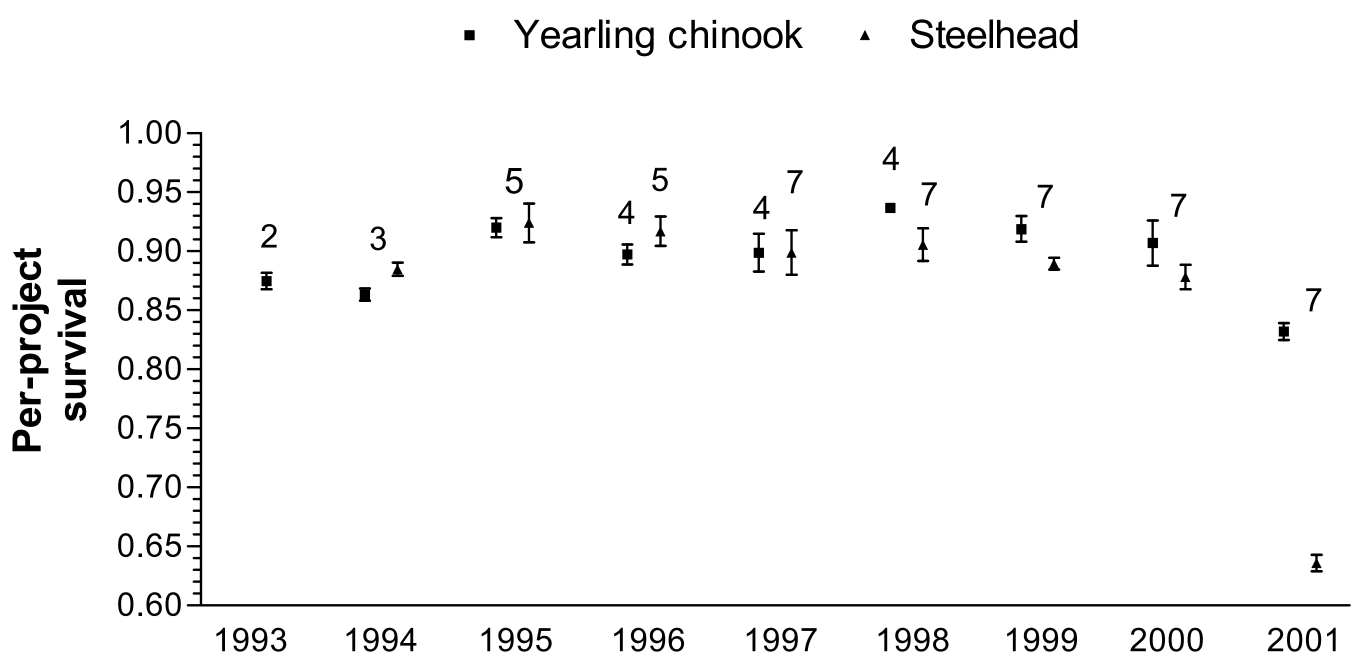

Figure 12. Estimated per-project survival (i.e., per dam/reservoir combination) with standard errors for yearling chinook salmon and steelhead from 1993 through 2000. Number above bar is the number of projects over which survival was estimated.

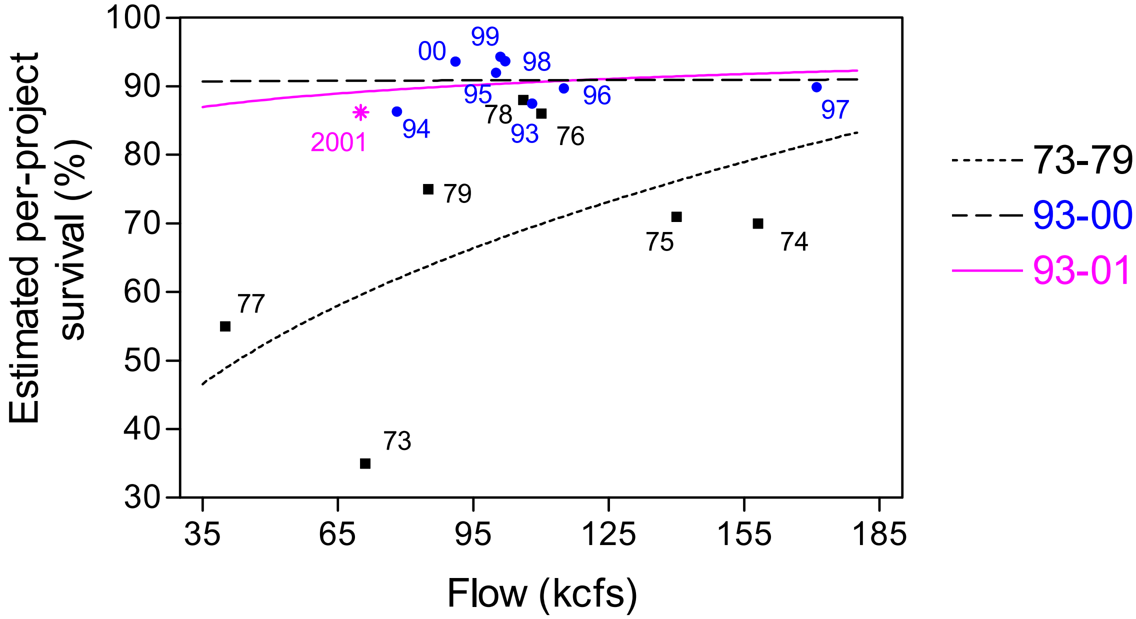

Figure 13. Per-project survival versus river flow for Snake River spring-summer chinook salmon. See text for details on the calculation of survival and flow indices.

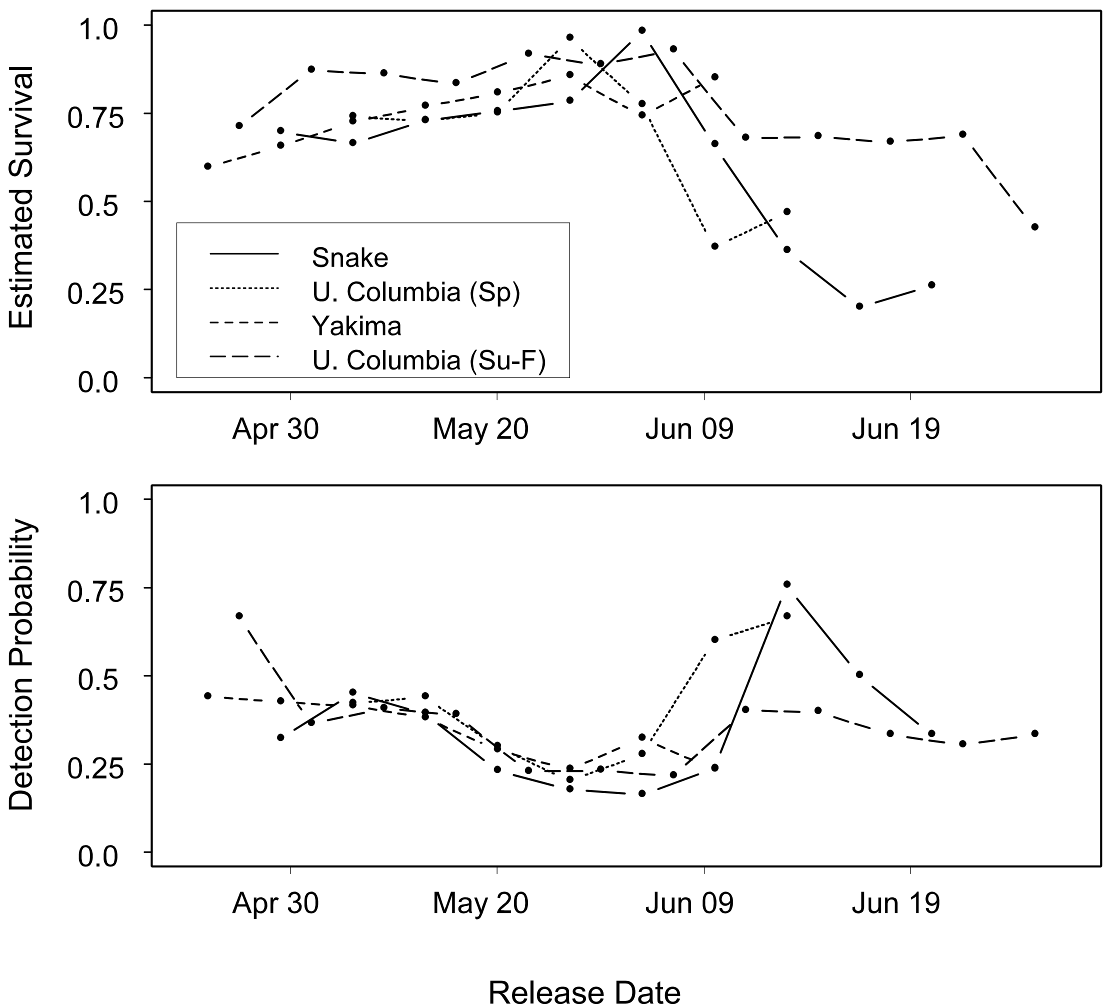

Figure 14. Estimated survival and detection probabilities for yearling chinook salmon migrating through John Day pool. Survival was estimated from McNary tailrace to John Day tailrace. Detection probabilities were estimated at John Day Dam. The fish were pooled into weekly groups based on detection date at McNary Dam. The points in the plots above represent the mid points of these weekly groups. The upper Columbia River fish were separated into spring and summer-fall stocks. See text for more details on the individual stocks. Abbreviations: Sp-Spring; Su-F-Summer-Fall.

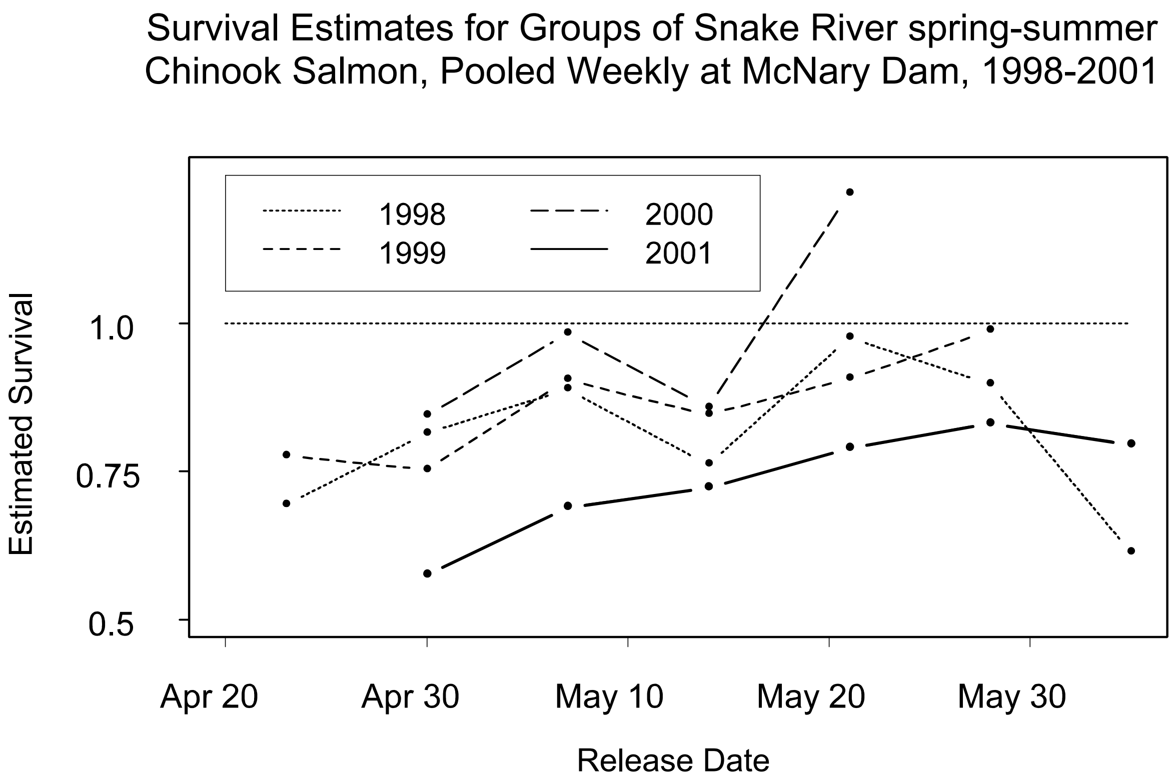

Figure 15. Survival estimates for Snake River spring-summer chinook salmon pooled into weekly "release" groups at McNary Dam, 1998-2001.

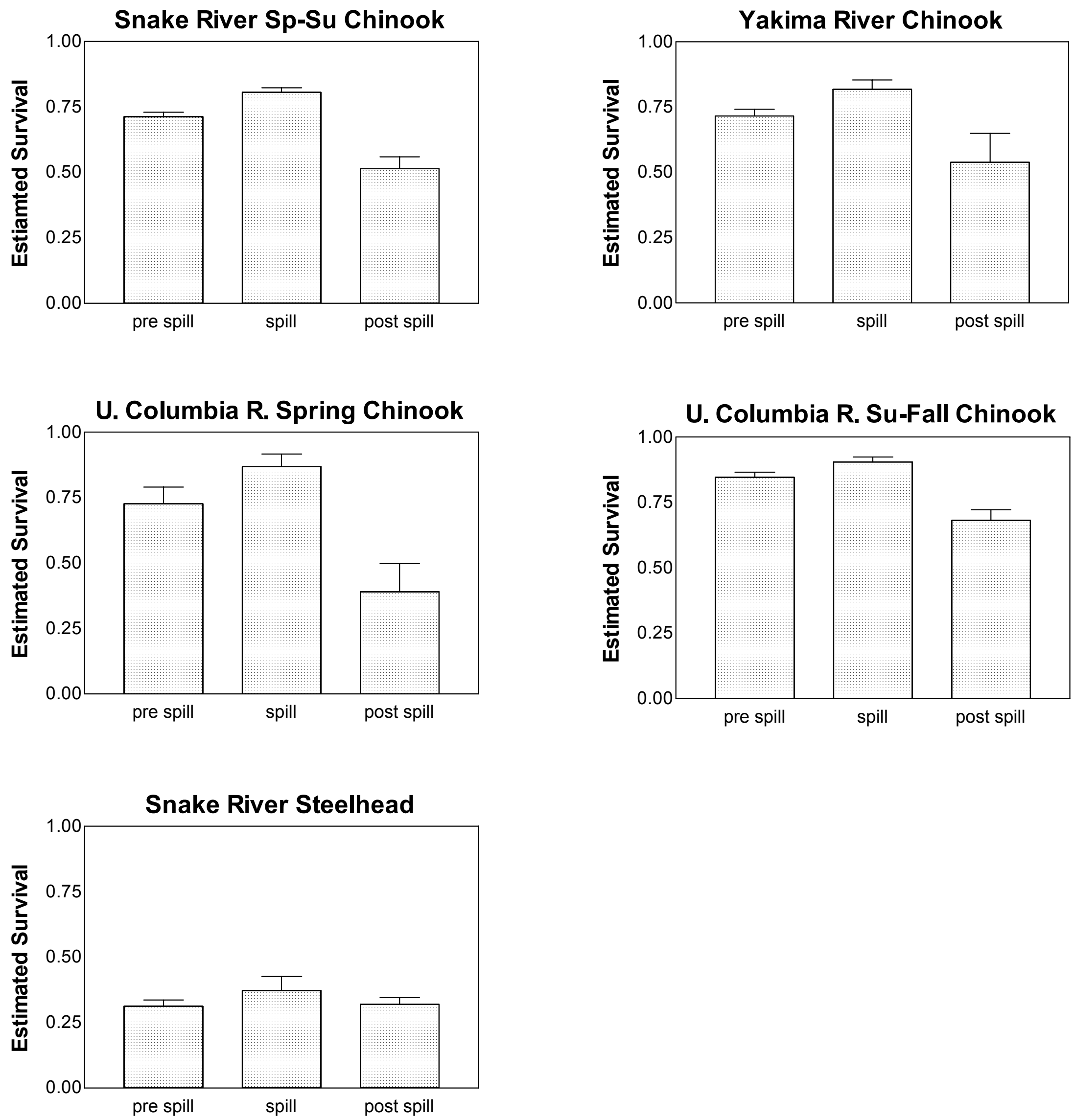

Figure 16. Estimated survival by stock for the pre-spill, spill, and post-spill periods for fish migrating through the McNary Dam to John Day reach. The line above each bar represents one standard error.

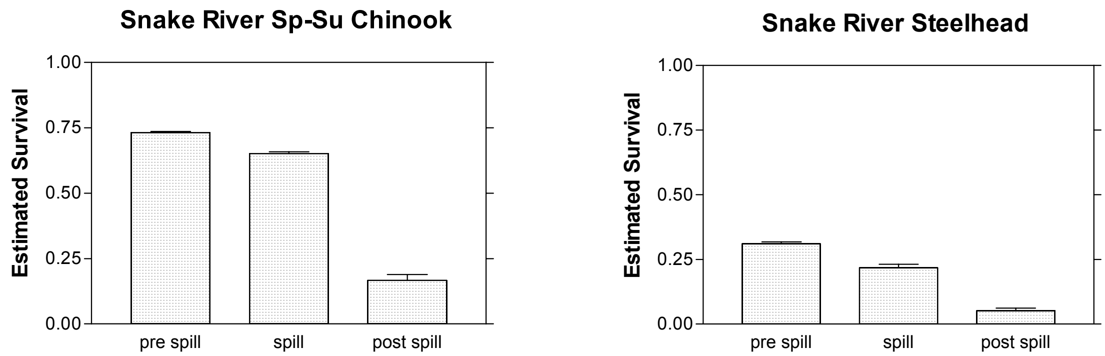

Figure 17. Estimated survival by stock for the pre-spill, spill, and post-spill periods for fish migrating through the Lower Monumental Dam to McNary Dam reach. The line above each bar represents one standard error.